National Aeronautics and Space Administration

Partner

Satellite Data for Air Quality

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part of the Earth Sciences Division (ESD)

at the NASA Goddard Space Flight Center (GSFC)

Outline for the presentation

Introduction

- The global data gap and the role of NASA in air quality measurement

Satellite Data for Air Quality Applications

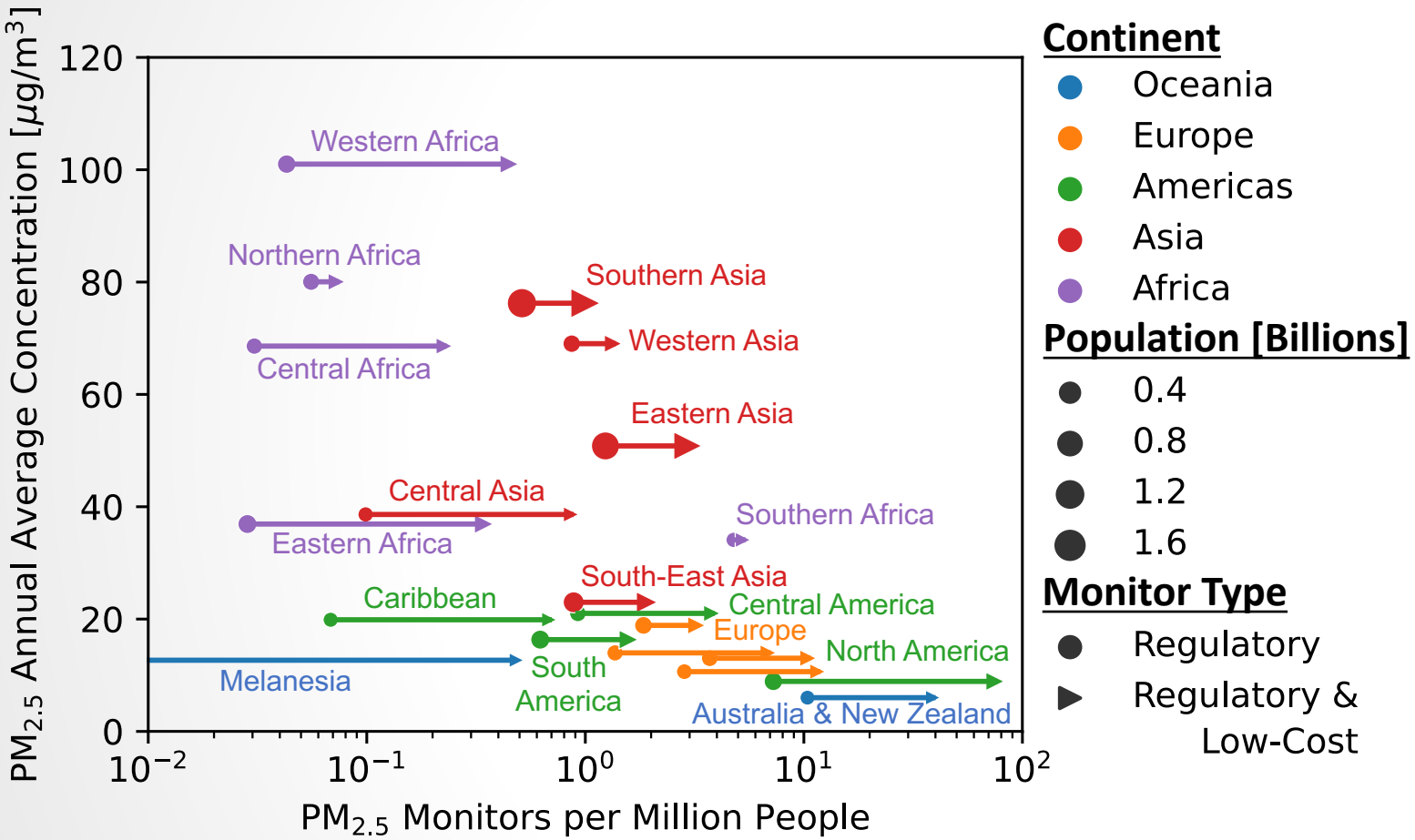
- Basic concepts: remote sensing, orbits, resolution, data processing levels
- Aerosols: aerosol optical depth, MODIS, VIIRS, EUMETSET, MAIA, PACE
- Trace Gases: OMI, TROPOMI, Ozone, NO_2, Formaldehyde, SO_2, CO, Methane

Applications involving satellite data

- Relationship of satellite data with surface concentrations
- Global air quality modeling and forecasting with NASA GEOS-CF
- Multi-source data fusion for sub-city-scale air quality

Data Access, Visualization, and Training Resources

Global in-situ air quality data are sparse



Many regions (especially Africa & Asia) feature high $PM_{2.5}$ concentration but low per-capita $PM_{2.5}$ monitor density, leading to **poor AQ data coverage**.

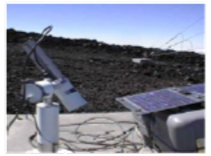
Including low-cost sensors **increases per-capita AQ monitor density by up to an order of magnitude** in several major regions.

This highlights the need to integrate **openly accessible in-situ AQ data** with globally available **model and remote sensing data.**

Source: Malings et al. (2020). "Application of low-cost fine particulate mass monitors to convert satellite AOD to surface concentrations in North America and Africa." *Atmospheric Measurement Techniques.* DOI: 10.5194/amt-13-3873-2020.
Updated analysis based on open air quality data available from openAQ.org

Sources of air quality information

traditional monitors



low-cost sensors

Ground Measurements

atmospheric observations

NASA contributions

Air & Space Observations

satellites

aircraft
balloons

Models

global models
regional models

Source: Gupta, P.; Follette-Cook, M. (2018). Satellite Remote Sensing of Air Quality. NASA Applied Remote Sensing Training Program (ARSET). https://appliedsciences.nasa.gov/join-mission/training/english/arset-satellite-remote-sensing-air-quality

Satellite instruments and retrievals

Source: NASA Earth Science https://science.nasa.gov/earth-science

Ground-based atmospheric column observations

AERONET
aerosol optical depth
(relevant to PM)

Source: https://aeronet.gsfc.nasa.gov/

Source: https://pandora.gsfc.nasa.gov/

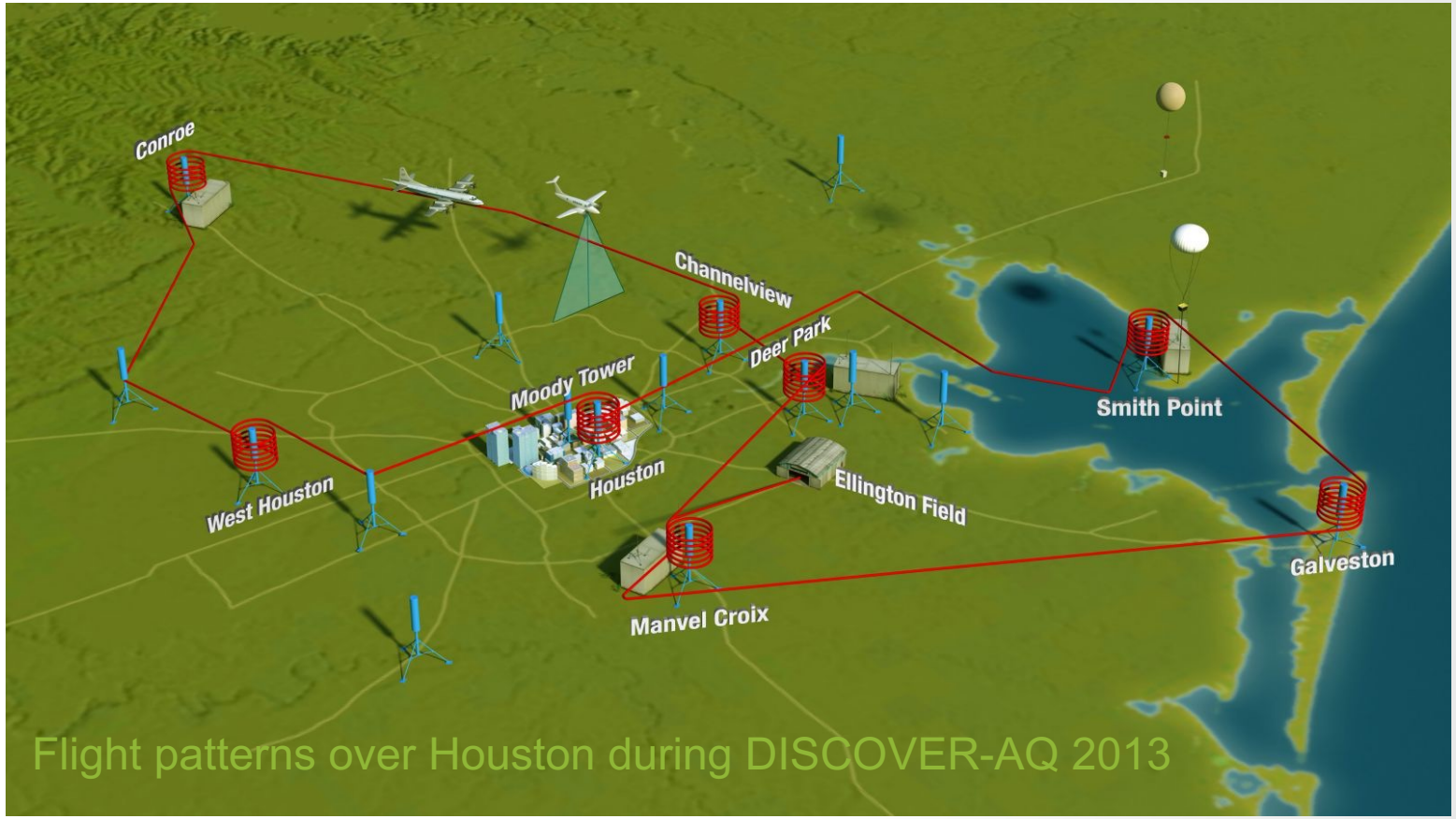
PANDORA
atmospheric gases
(NO_2, Ozone)

Airborne air quality campaigns

Typically, these campaigns gather data to improve satellite retrieval algorithms and models.

Instruments aboard NASA DC-8 Aircraft (photo credit: Pedro Campuzano-Jost)

Source: https://espo.nasa.gov/firex-aq/content/FIREX-AQ

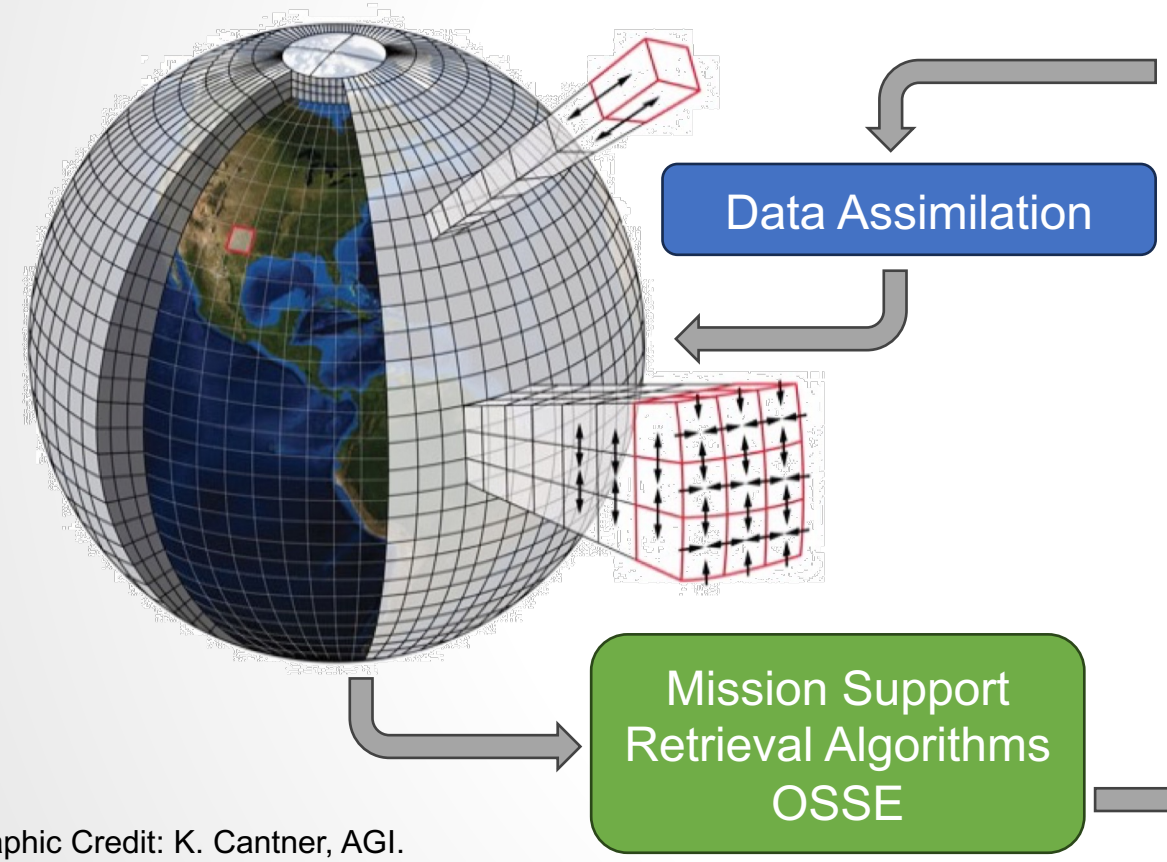


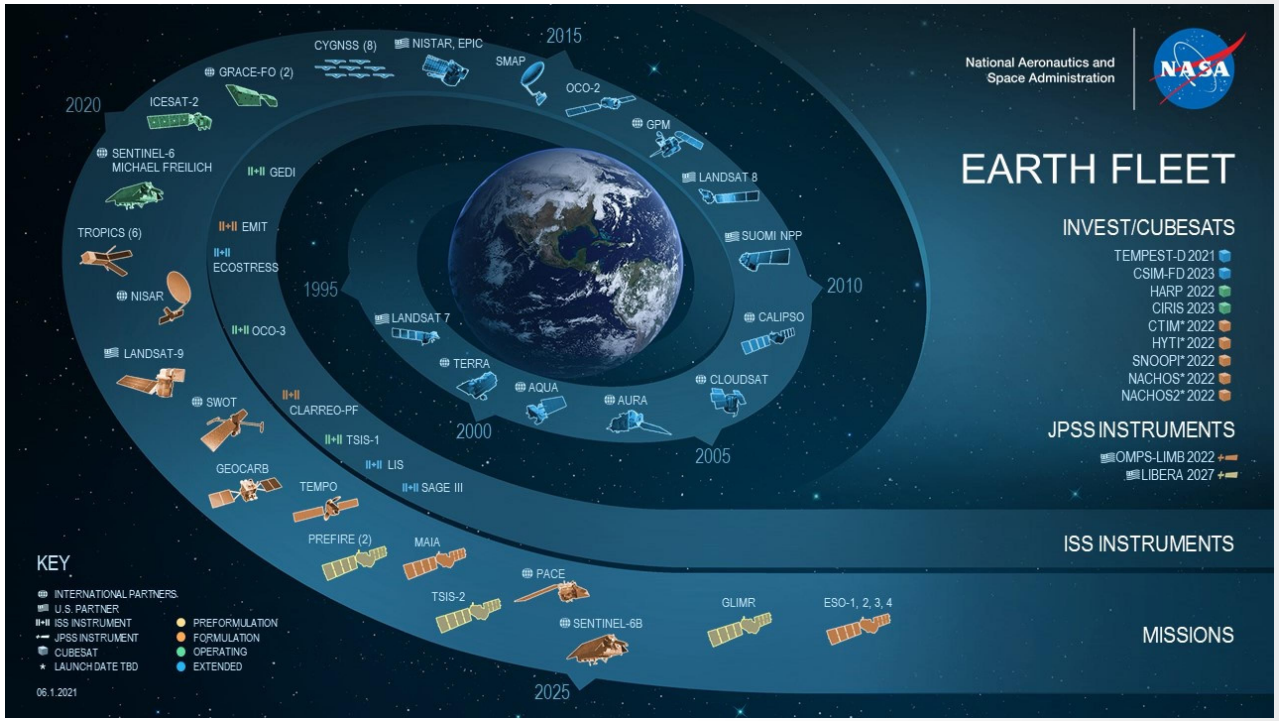
Flight patterns over Houston during DISCOVER-AQ 2013

Source: NASA LARC DISCOVER-AQ campaign webpage https://www-air.larc.nasa.gov/missions/discover-aq/discover-aq.html

NASA Global Modeling & Assimilation Office (GMAO)

The **GMAO** uses **computer models** and **data assimilation** to enhance NASA's program of **Earth Observations**.





Source: NASA Earth Science https://science.nasa.gov/earth-science

Graphic Credit: K. Cantner, AGI.
https://wxguys.ssec.wisc.edu/2019/03/04/models/

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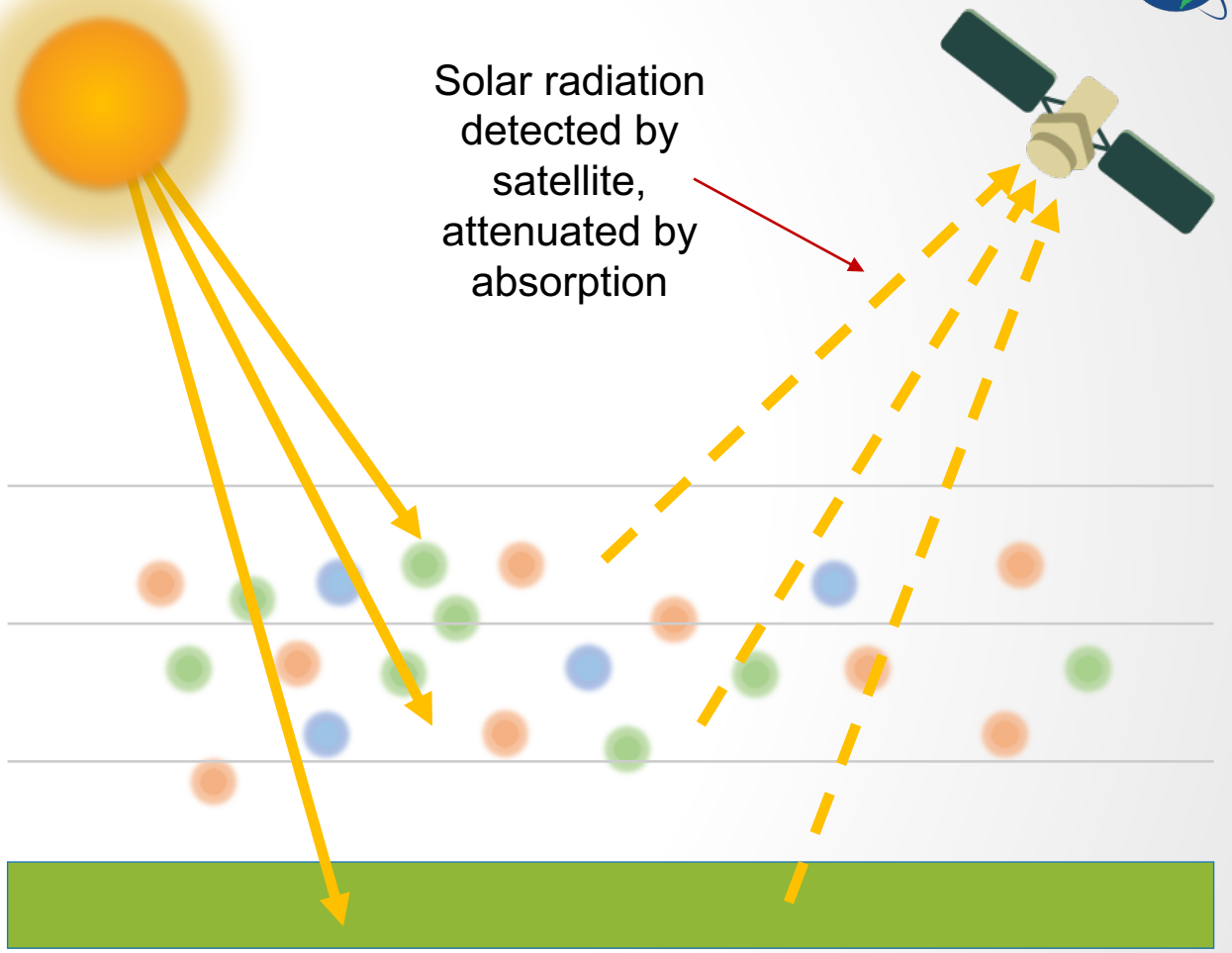
Satellite Data for Air Quality Basic Concepts

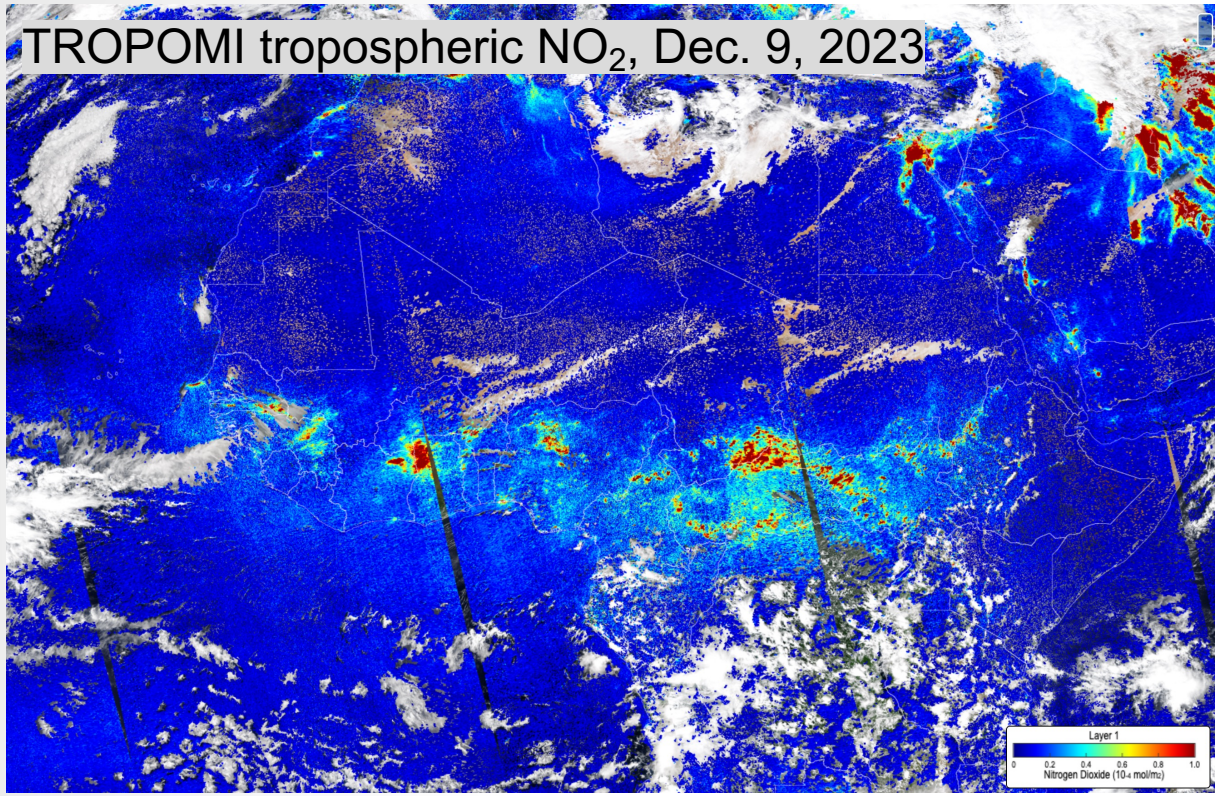
Basic principles of remote sensing

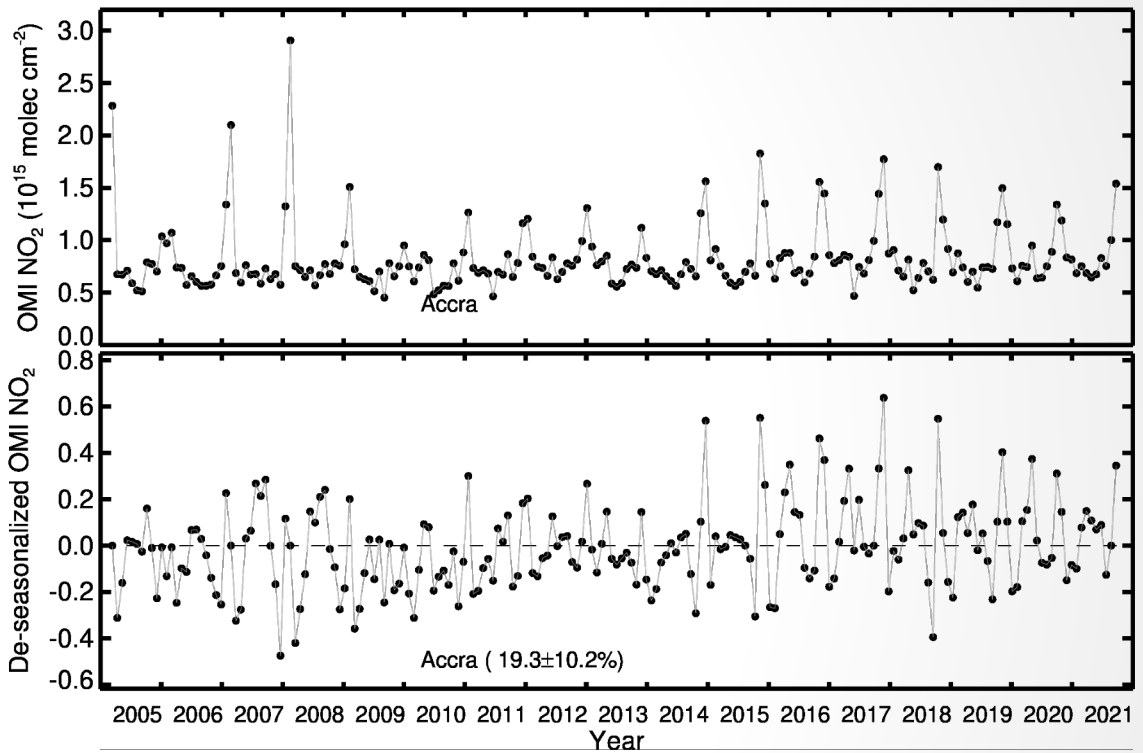
- Satellites typically detect **solar radiation** backscattered from the Earth.
- Retrieval algorithms use physical principles to infer **geophysical quantities** from this data, such as:
  - **aerosol optical depth** for all aerosols in the atmosphere, using visible light.
  - **trace gas total column density** using the "spectral fingerprints" of many gases.
- Usually, there is little information on the **vertical distribution** of aerosols or trace gases, although some limb view or active sensors can do this.



Source: Gupta, P.; Follette-Cook, M.; Strode, S.; Malings, C. (2023). ARSET - NASA Air Quality-Focused Remote Sensing for EPA Applications. NASA Applied Remote Sensing Training Program (ARSET). http://appliedsciences.nasa.gov/join-mission/training/english/arset-nasa-air-quality-focused-remote-sensing-epa-applications

What satellite data CAN do for air quality

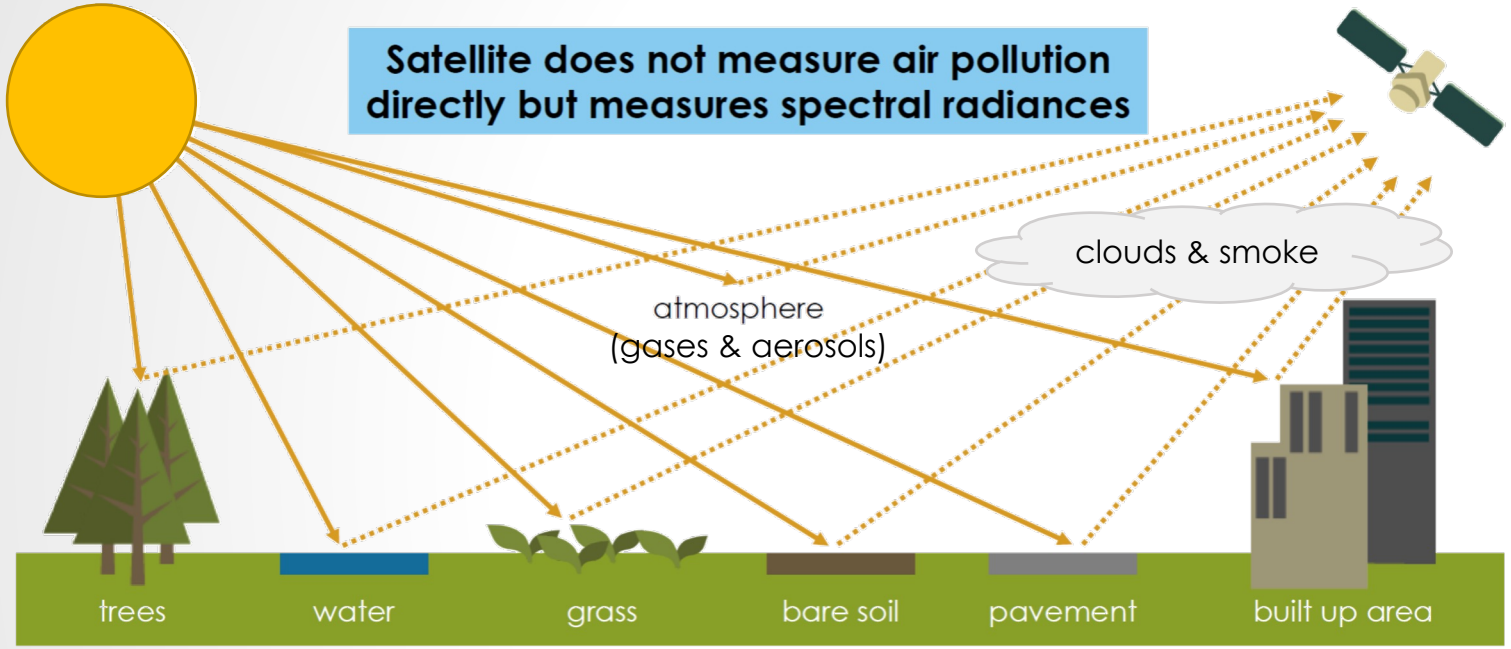


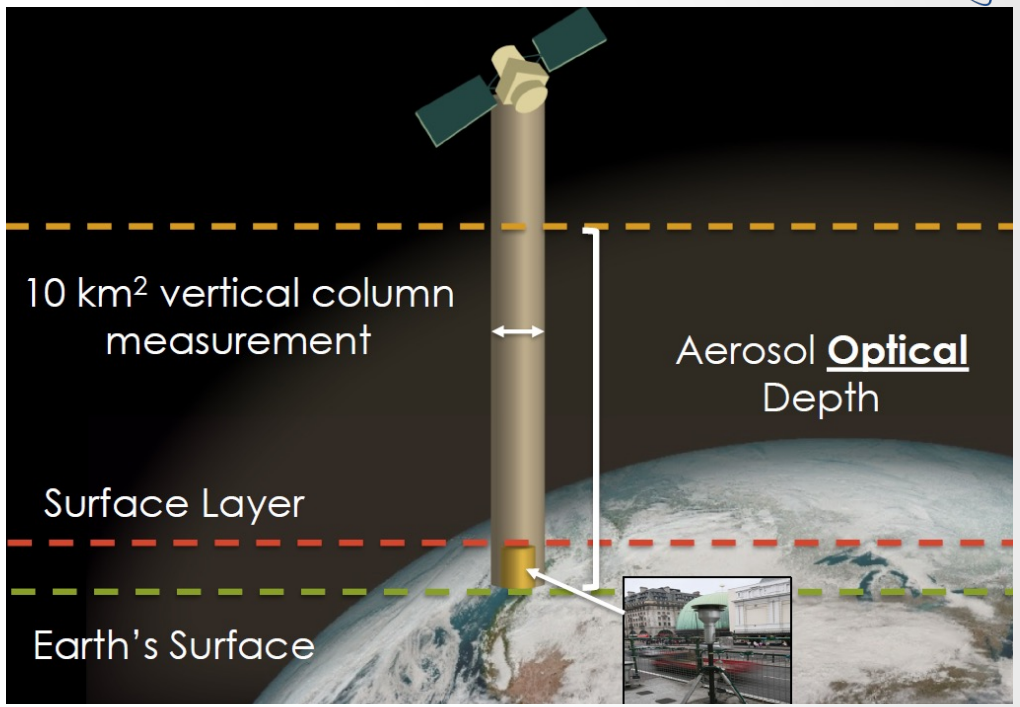


- **Examine a large area**: where are the hotspots? how is long-range transport happening?
- **Track changes over time:** how much has the average concentration over an area changed over time?
- **A picture is worth a million datapoints:** Anyone can understand a satellite photo of a smoke plume.

Sources: NOAA JSTAR Mapper website https://www.star.nesdis.noaa.gov/mapper/
NASA GSFC Nitrogen Dioxide Trends for World Cities https://airquality.gsfc.nasa.gov/no2/world

What satellite data CANNOT do for air quality





- **See at night:** satellites measure the properties of reflected sunlight passing through the atmosphere.
- **See through clouds:** most satellite measurements are blocked by cloud cover.
- **See what is happening at "nose level":** satellites measure quantities in the whole atmosphere.
- **See at different times of day:** polar-orbiting satellites will observe a location once per day.

Source: Gupta, P.; Follette-Cook, M. (2018). Satellite Remote Sensing of Air Quality. NASA Applied Remote Sensing Training Program (ARSET). https://appliedsciences.nasa.gov/join-mission/training/english/arset-satellite-remote-sensing-air-quality

Some common satellite data terms

- Satellite v. Instrument

Source: Follette-Cook, M.; Prados, A.; Gupta, P. (2020). An Inside Look at How NASA Measures Air Pollution. NASA Applied Remote Sensing Training Program (ARSET). https://appliedsciences.nasa.gov/join-mission/training/english/arset-inside-look-how-nasa-measures-air-pollution

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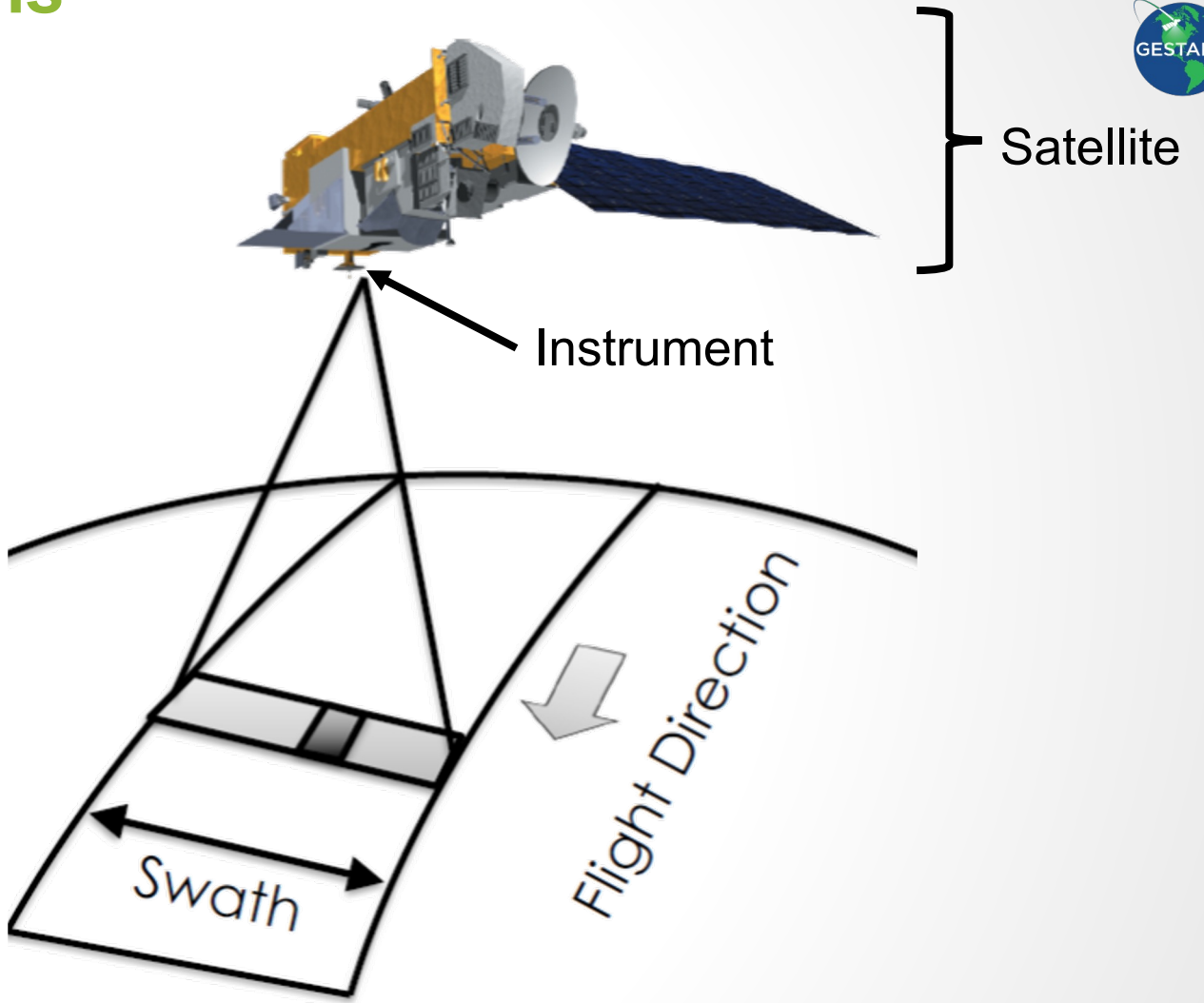
- Swath or Field of Regard



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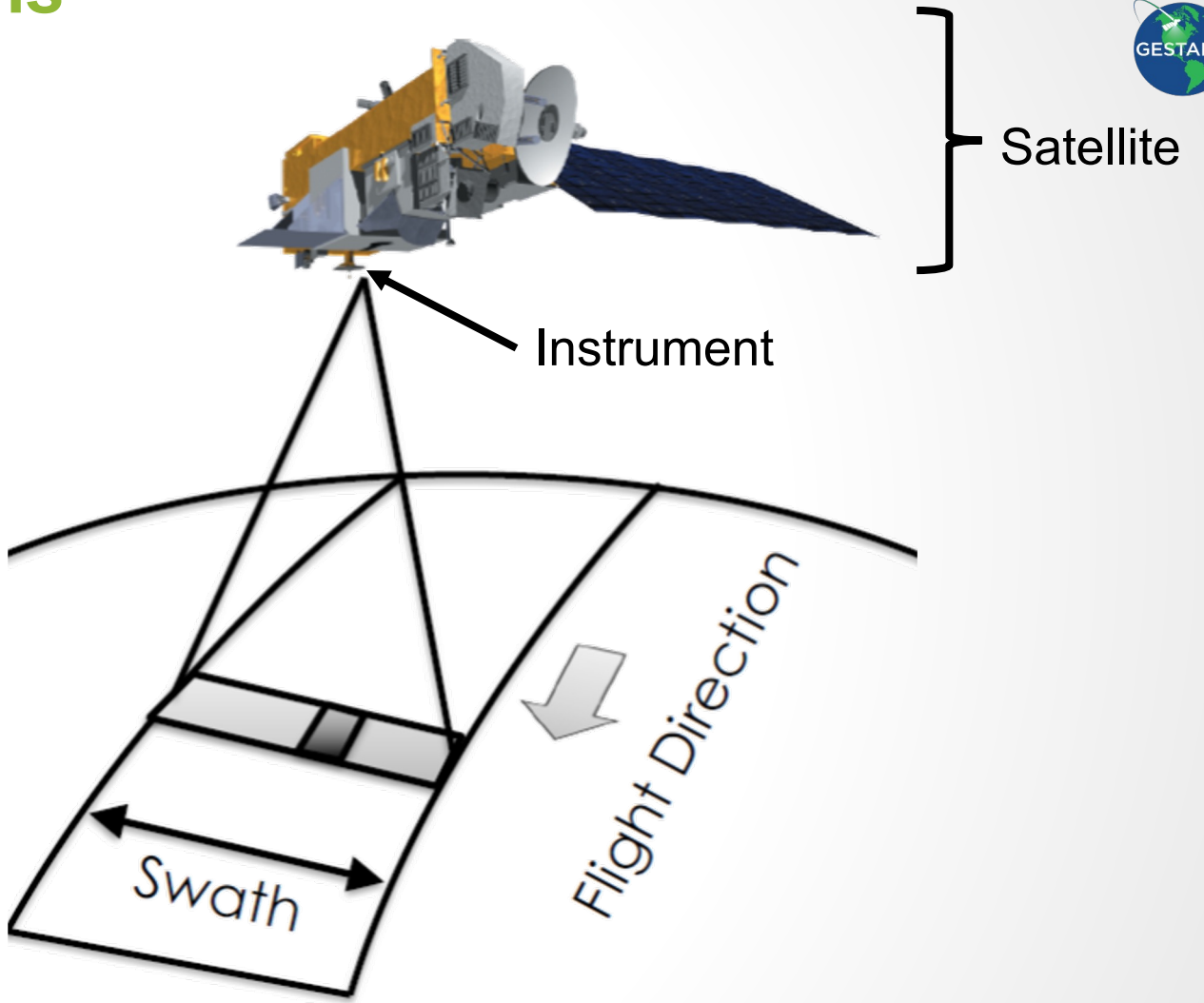

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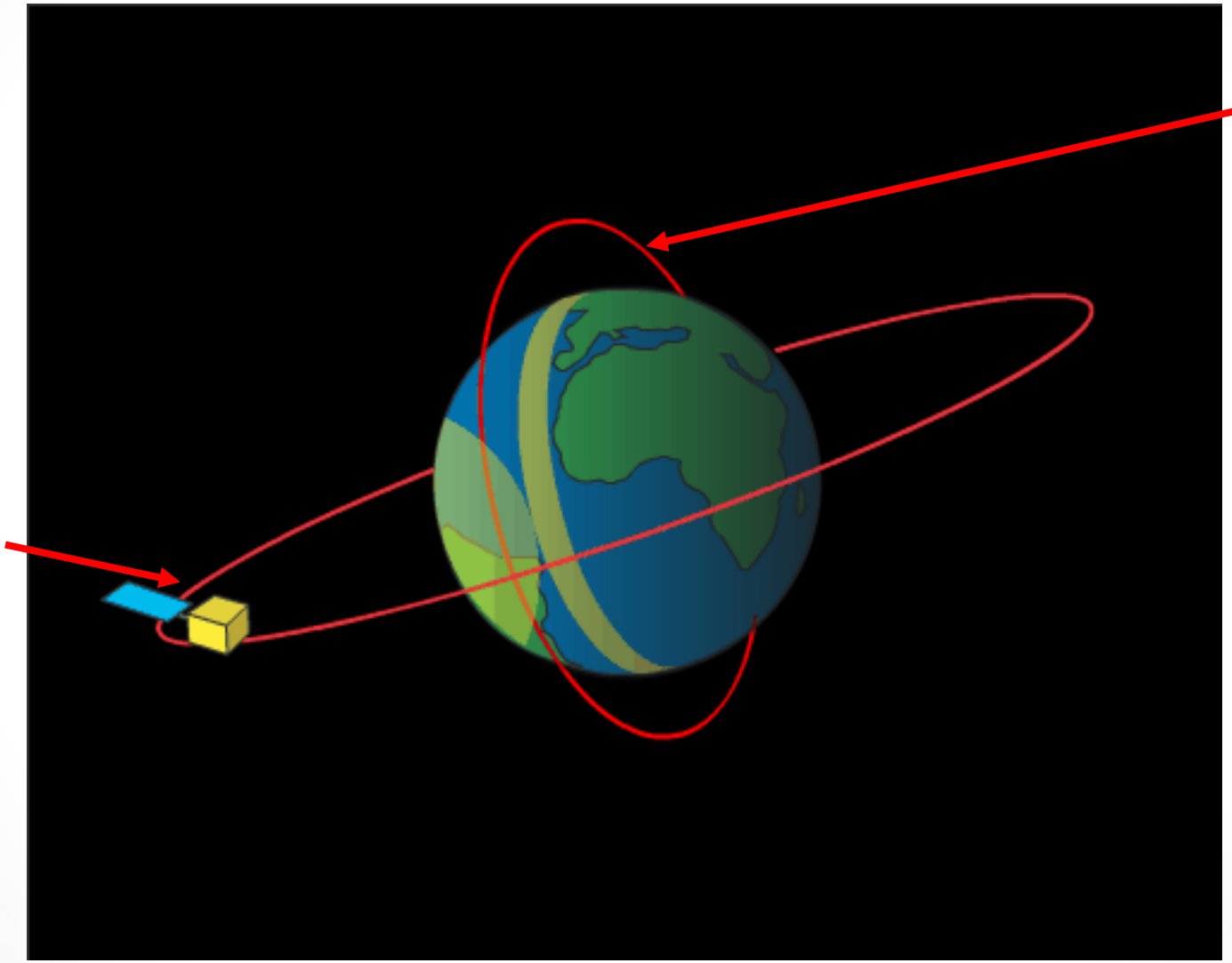
Common types of orbits for air quality satellites



Polar Orbit

Observes a location about once a day (weather permitting)

Observes at about the same time of day (sun-synchronous)

Geostationary Orbit

Observes the same area all the time

Observes throughout the day (weather and light permitting)

source: NOAA
https://scijinks.gov/orbit/

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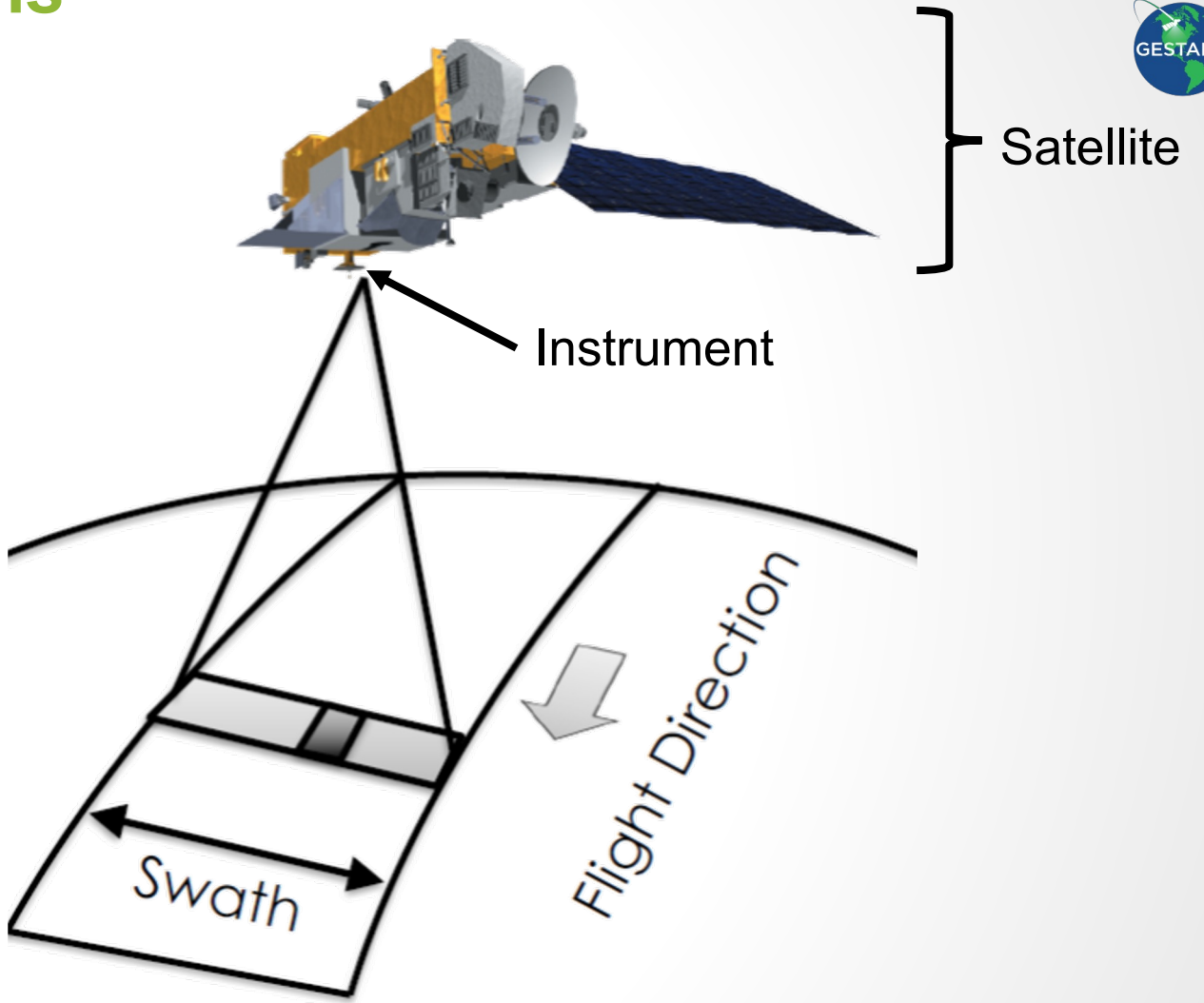
- Equator crossing time
- Ascending/Descending
- Temporal Resolution/Return period



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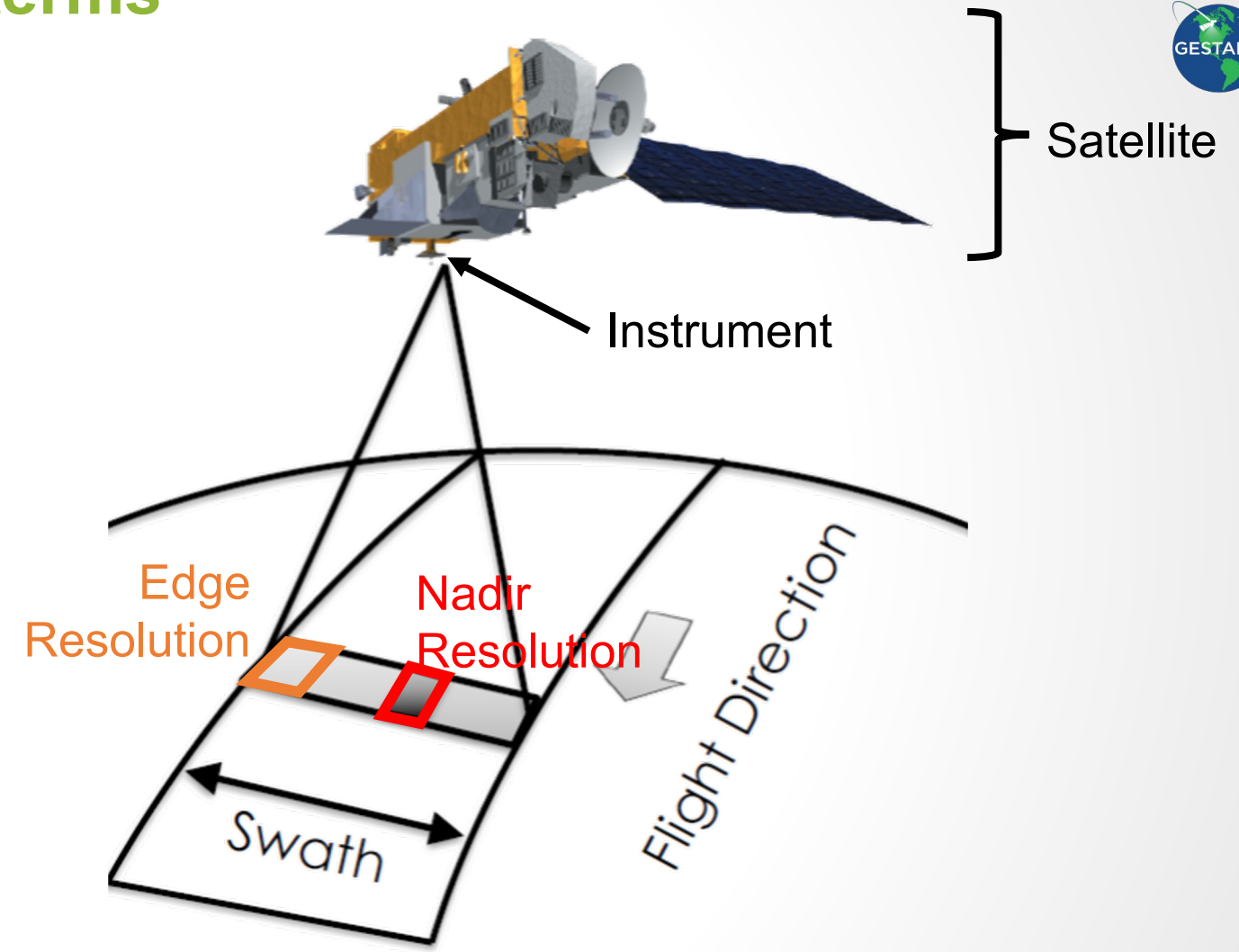

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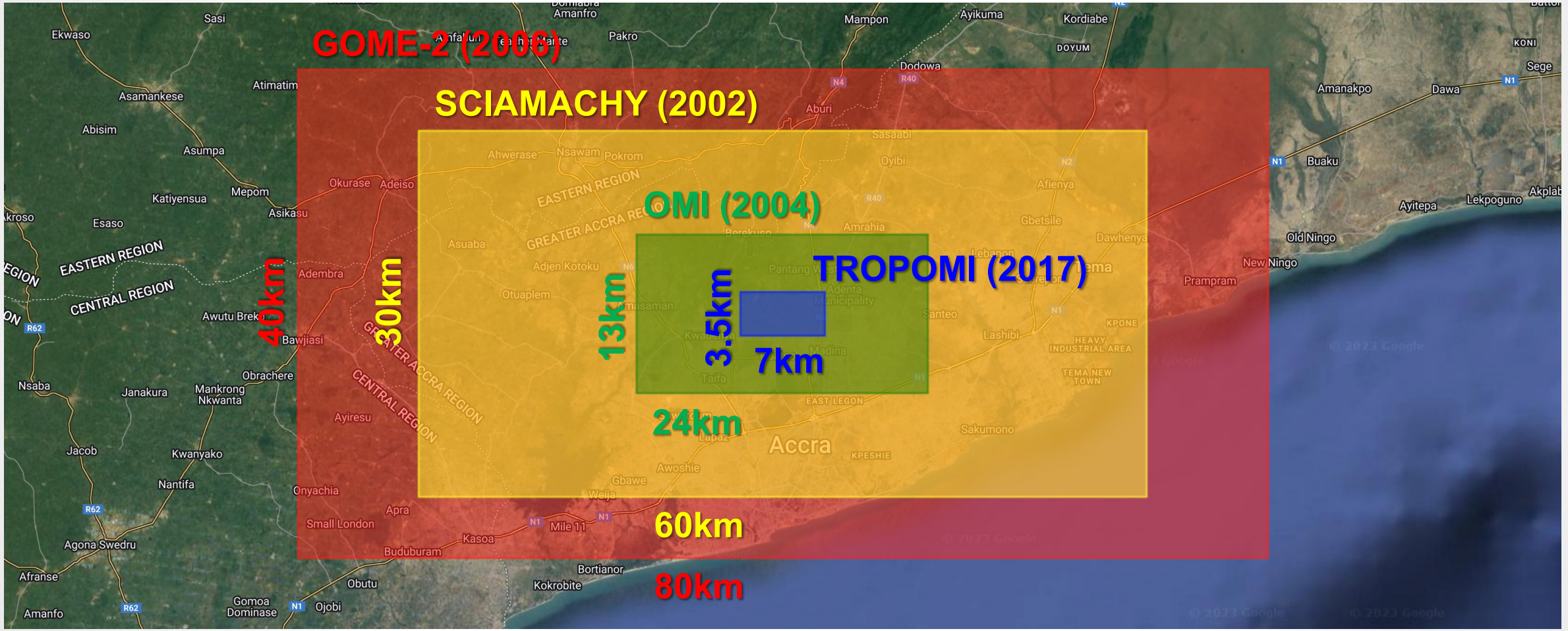
Spatial resolution has been improving over time



Source: Custom code in Google Earth Engine https://code.earthengine.google.com/

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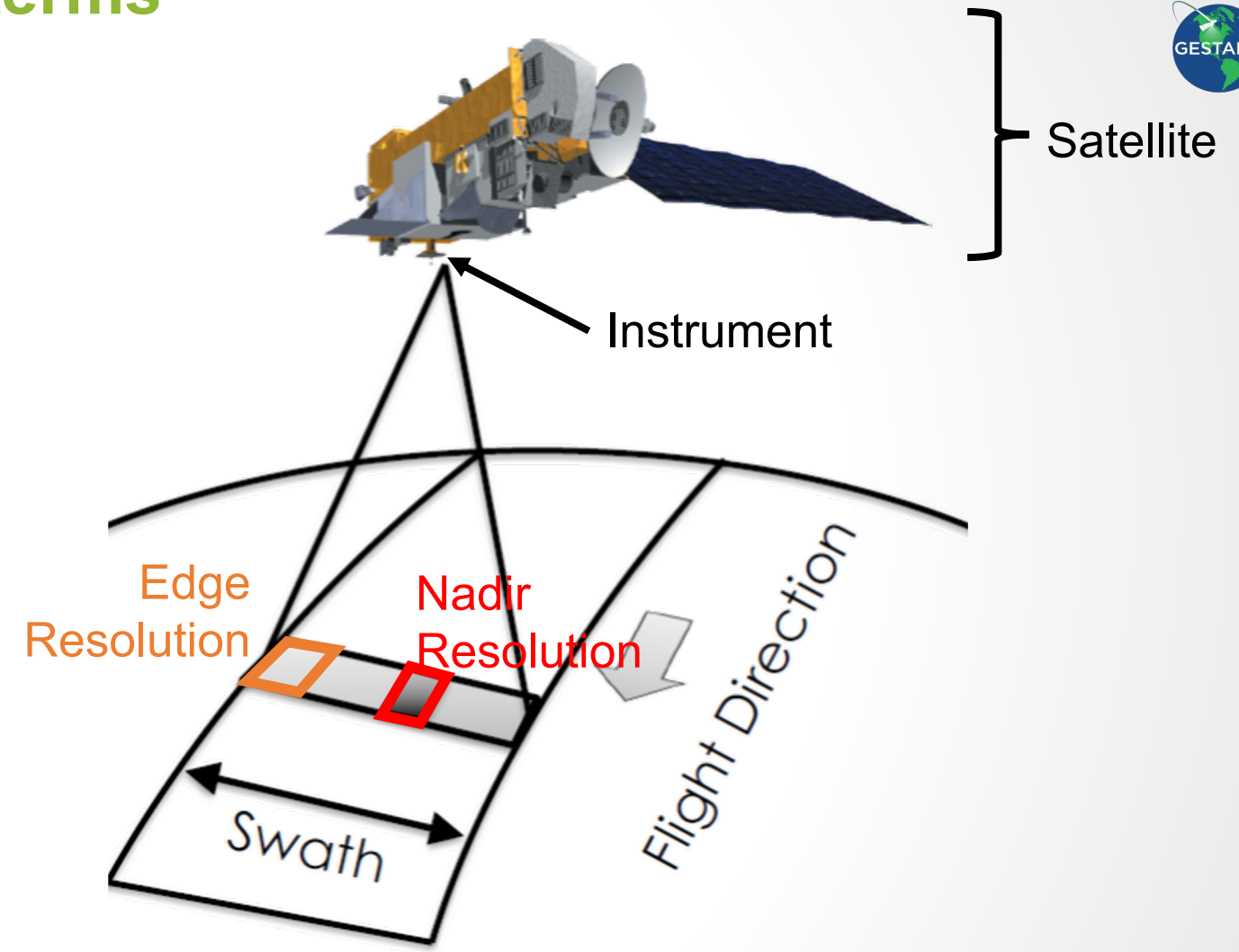
- Spatial Resolution (nadir v. edge)
- Spectral Resolution



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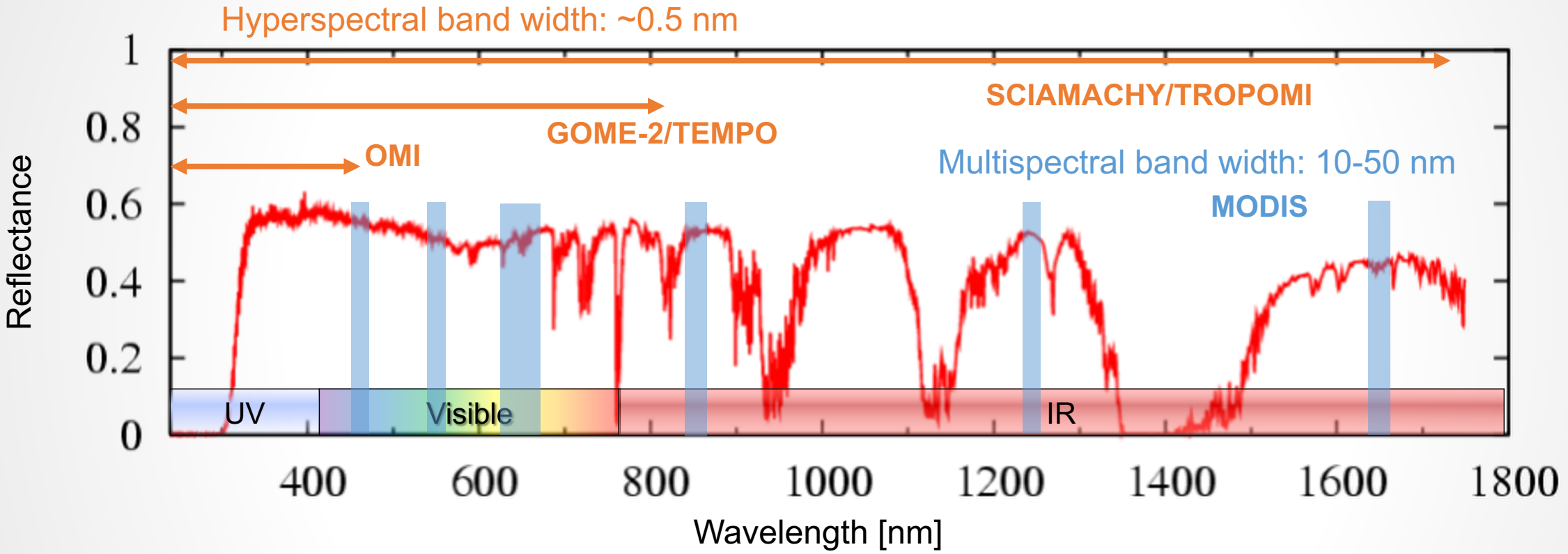
Spectral resolution & what satellites can remotely measure



UV & vis. multispectral data → aerosol information
Aerosol Optical Depth (AOD) @ 550nm

UV & vis. hyperspectral data → NO_2, SO_2, O_3*, HCHO

IR hyperspectral data → CO, CO_2, CH_4

*high O_3 concentrations in the stratosphere make near-surface measurements difficult

Source: Gupta, Follette-Cook, Strode, Malings (2023). ARSET - NASA Air Quality-Focused Remote Sensing for EPA Applications *NASA ARSET*.

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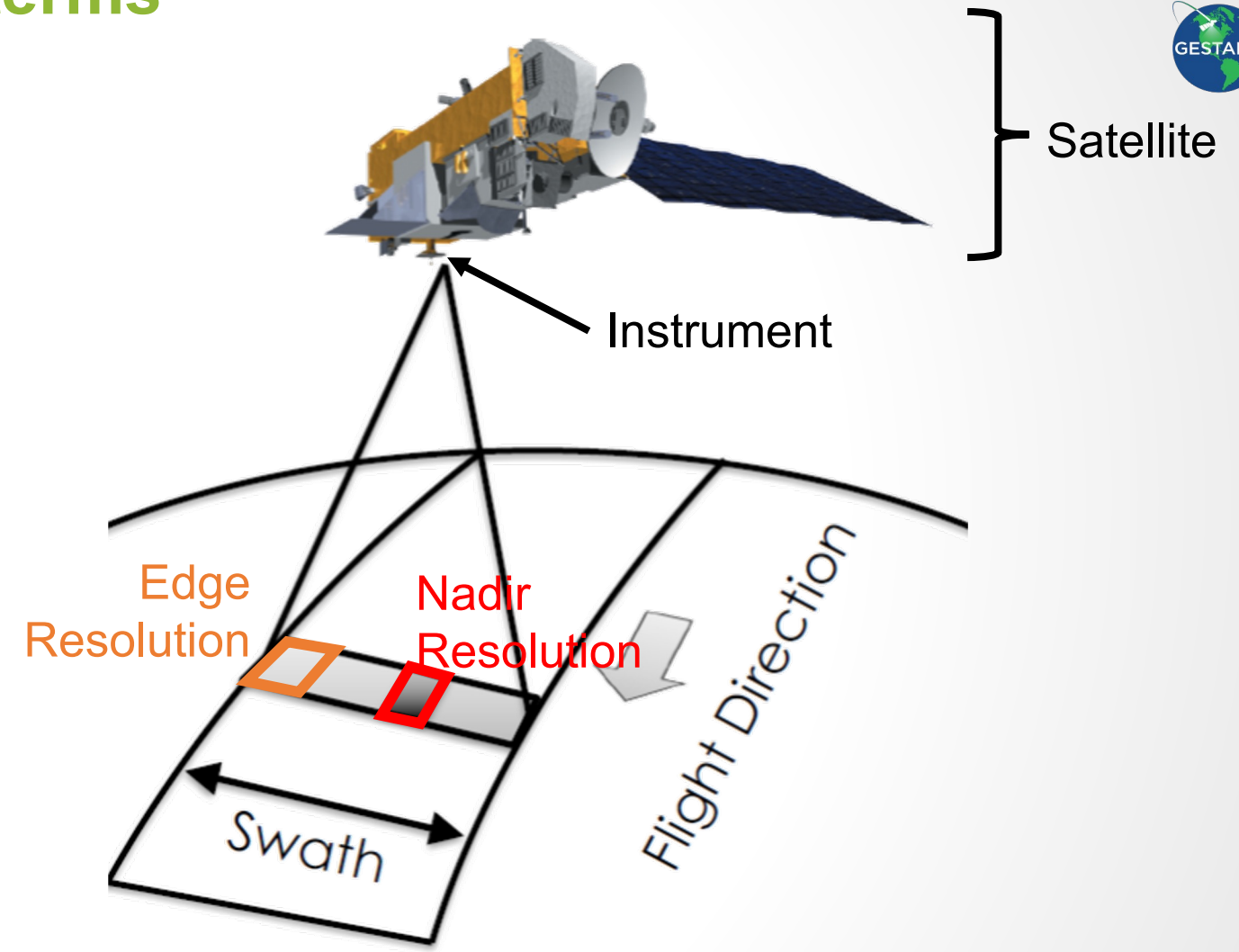
- Spectral Resolution
- Data product
- Column concentration
- Aerosol Optical Depth/Thickness



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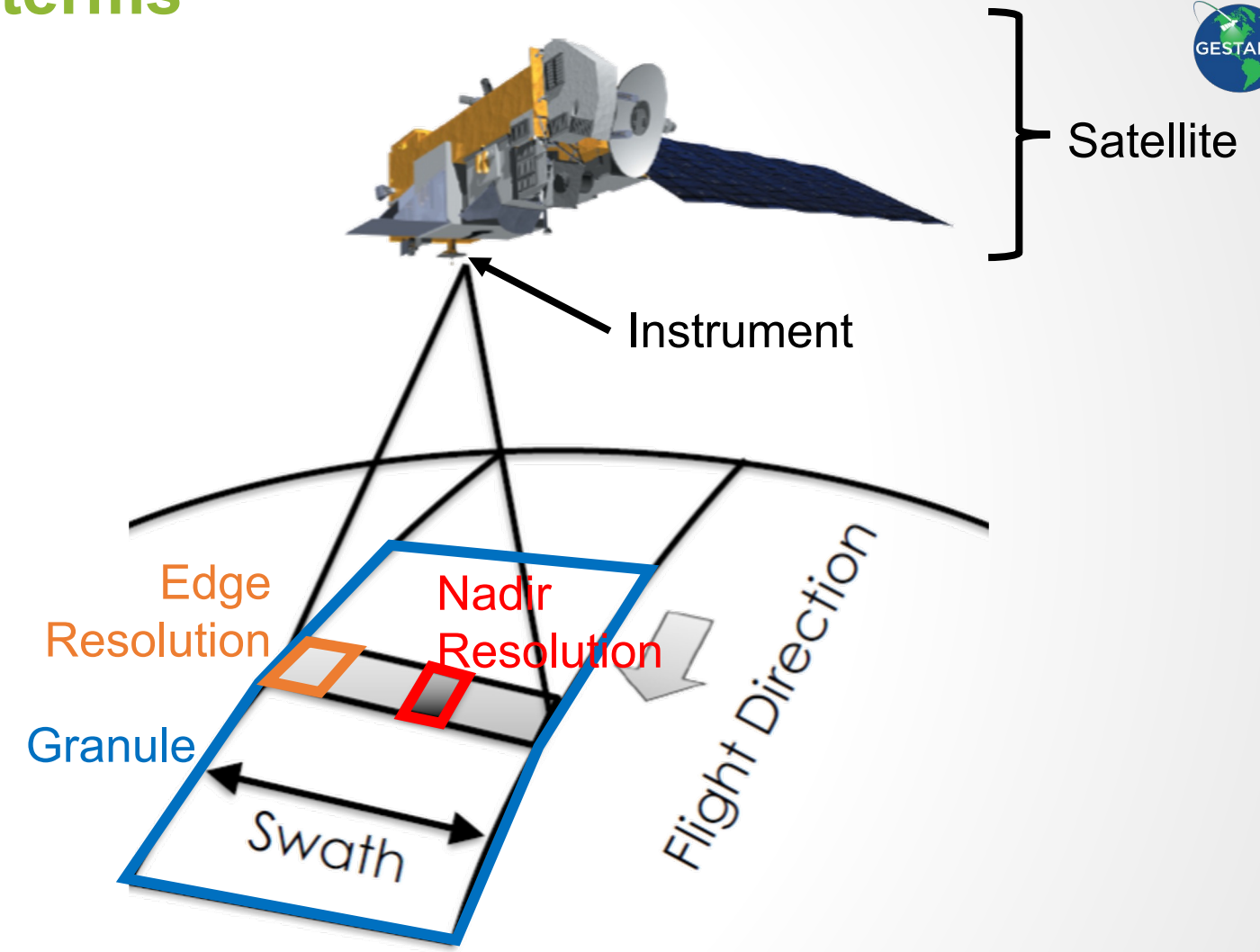
- Column concentration
- Aerosol Optical Depth/Thickness
- Granule



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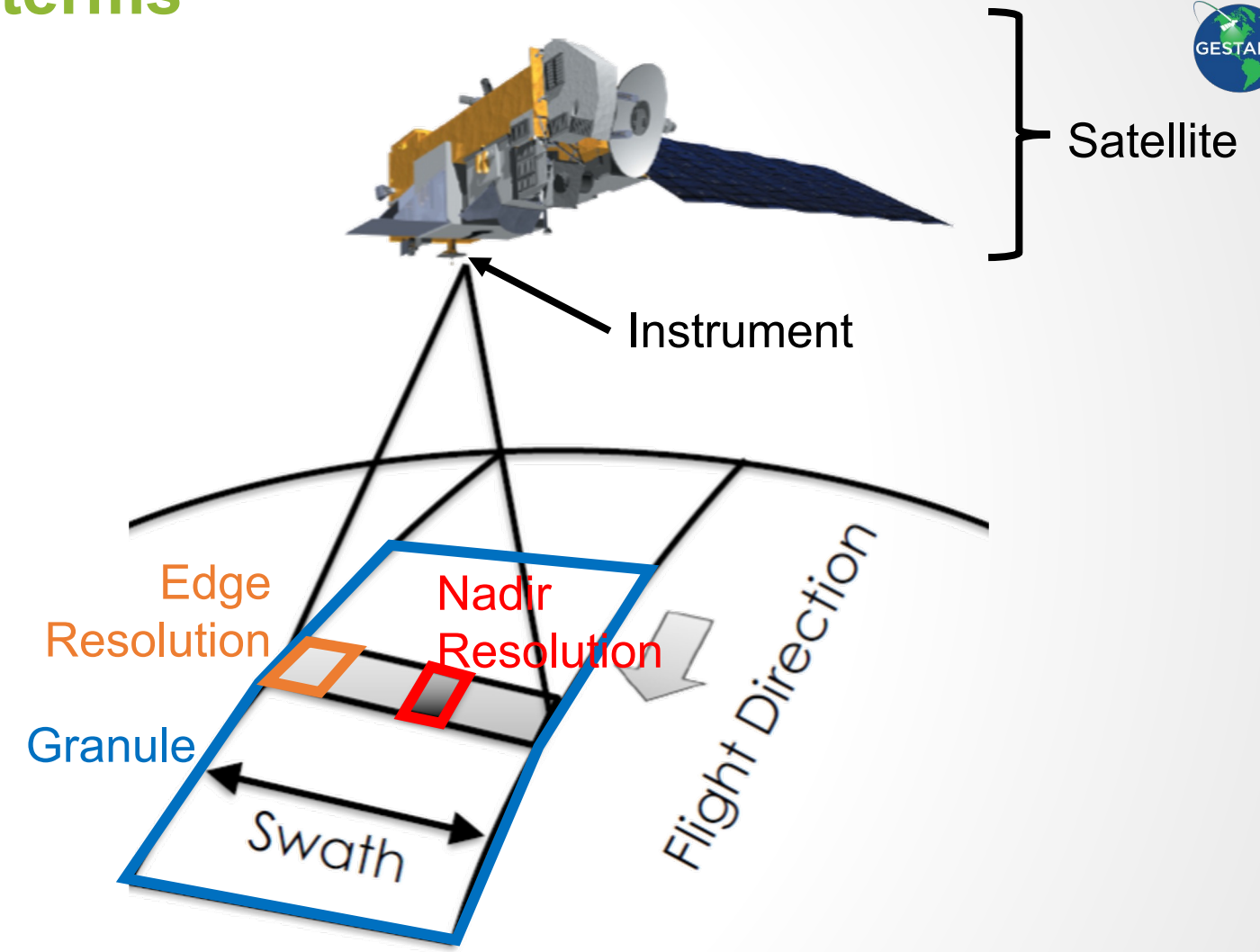
- Spectral Resolution
- Data product
- Column concentration
- Aerosol Optical Depth/Thickness
- Granule
- Processing level
- Quality flags and masks



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Satellite data processing levels

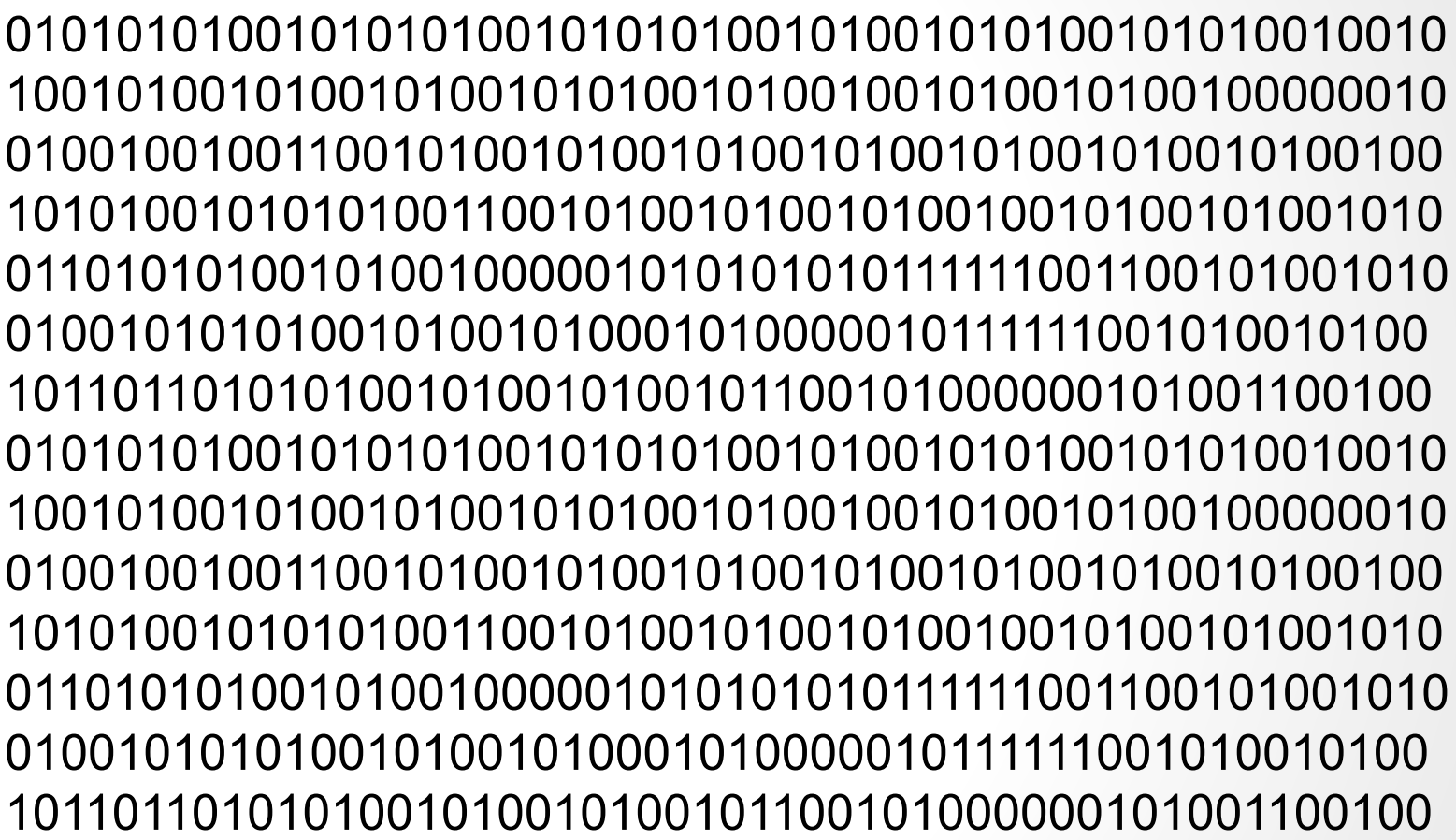
Level 0: Raw data

Level 1: Geo-referenced raw data

Level 2: Derived geophysical variables (e.g., column concentrations)

Level 3: Data re-mapped to uniform space & time grids

Level 4: Data combined together from multiple sources (e.g., satellite and model data)



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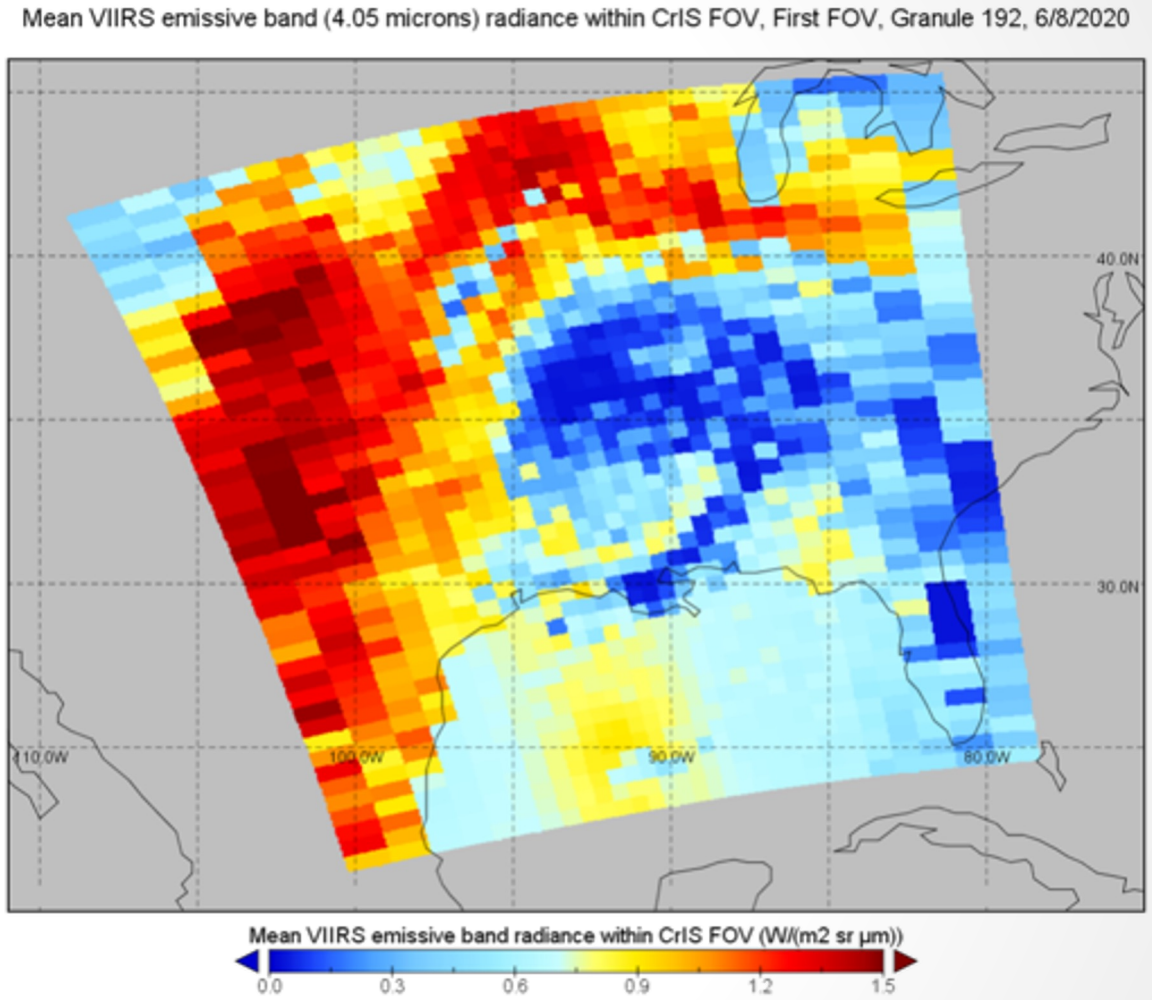

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NASA GES DISC https://disc.gsfc.nasa.gov/datasets/SNDRSNCrISL1BIMG_2/summary

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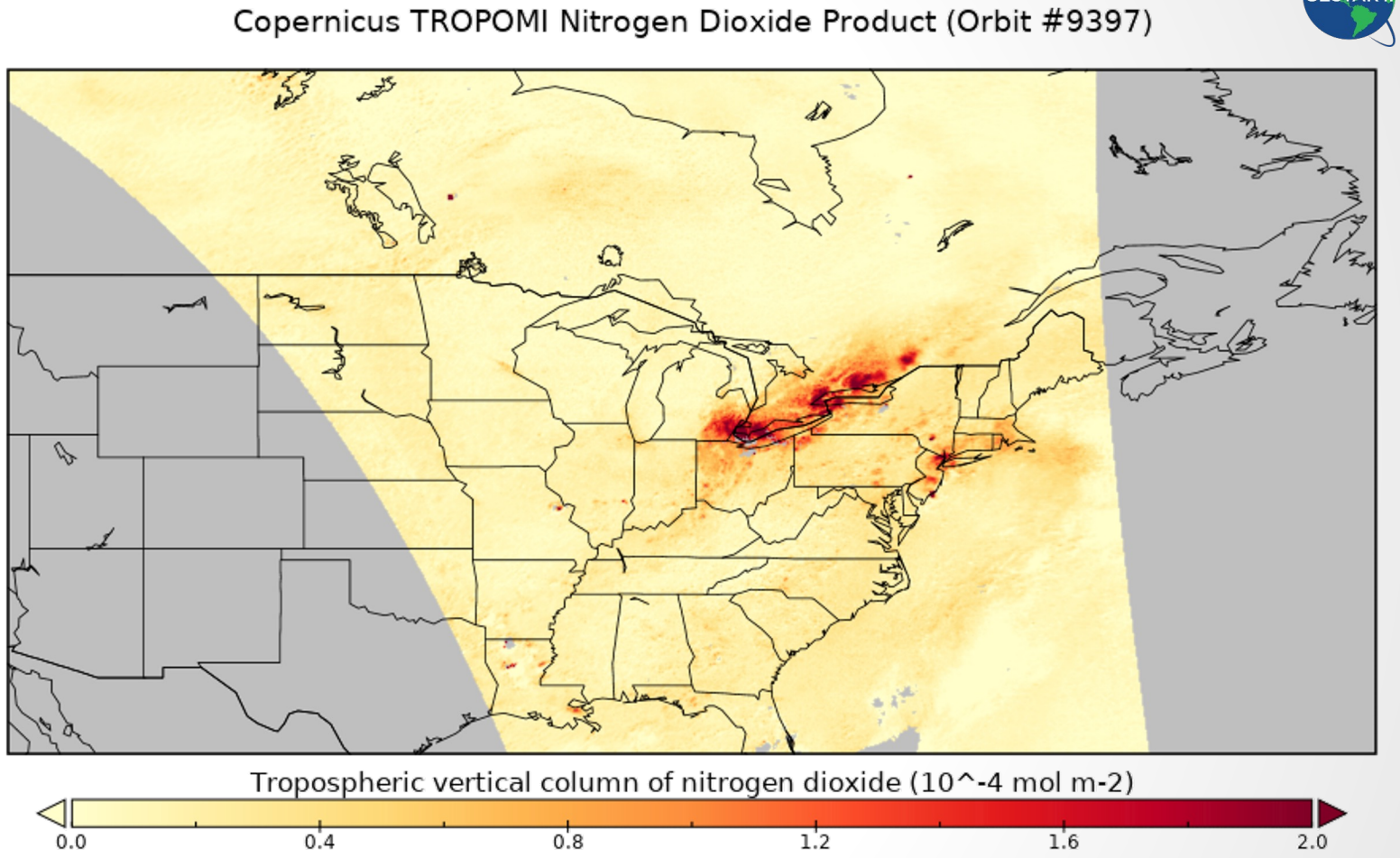

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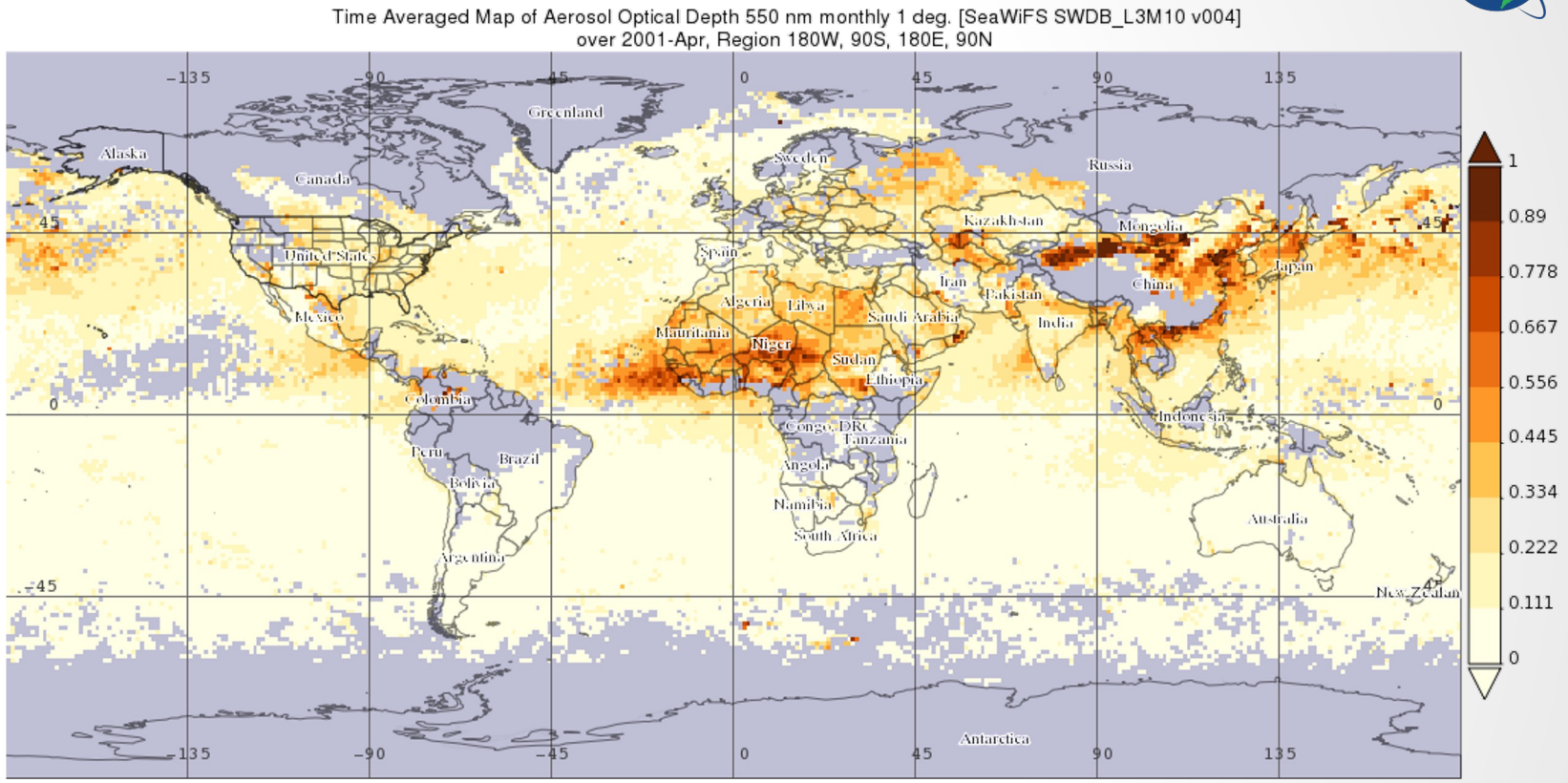

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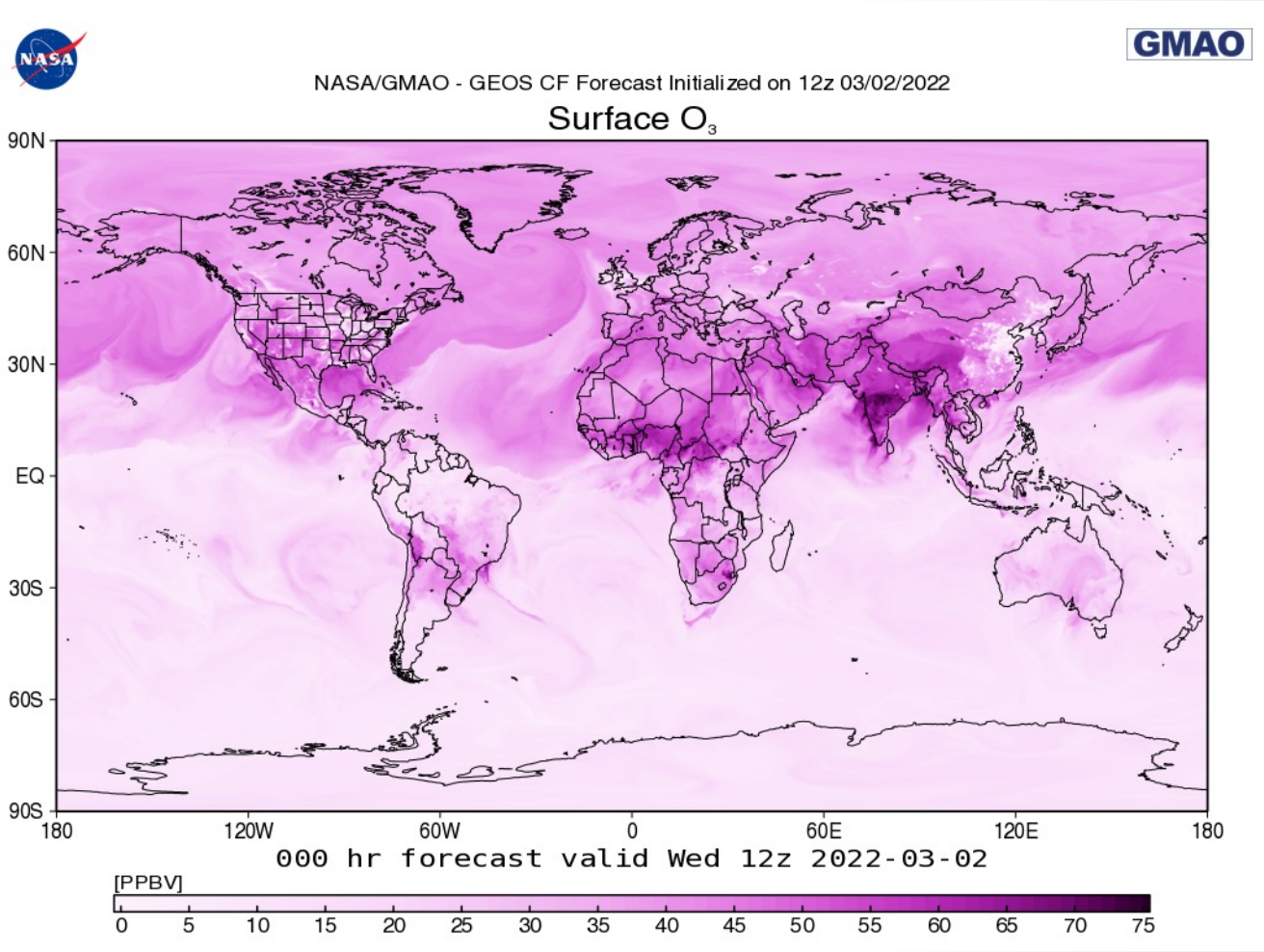

Source: NASA EarthData https://earthdata.nasa.gov/collaborate/open-data-services-and-software/data-information-policy/data-levels
NASA GMAO FLUID Tool https://fluid.nccs.nasa.gov/cf/classic_geos_cf/?one_click=1&tau=000&stream=GEOSCFFC&level=0&region=global&fcst=20220302T120000&field=o3sfc

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Satellite Data for Air Quality Aerosols & Particulate Matter

aerosol optical depth from satellite instruments

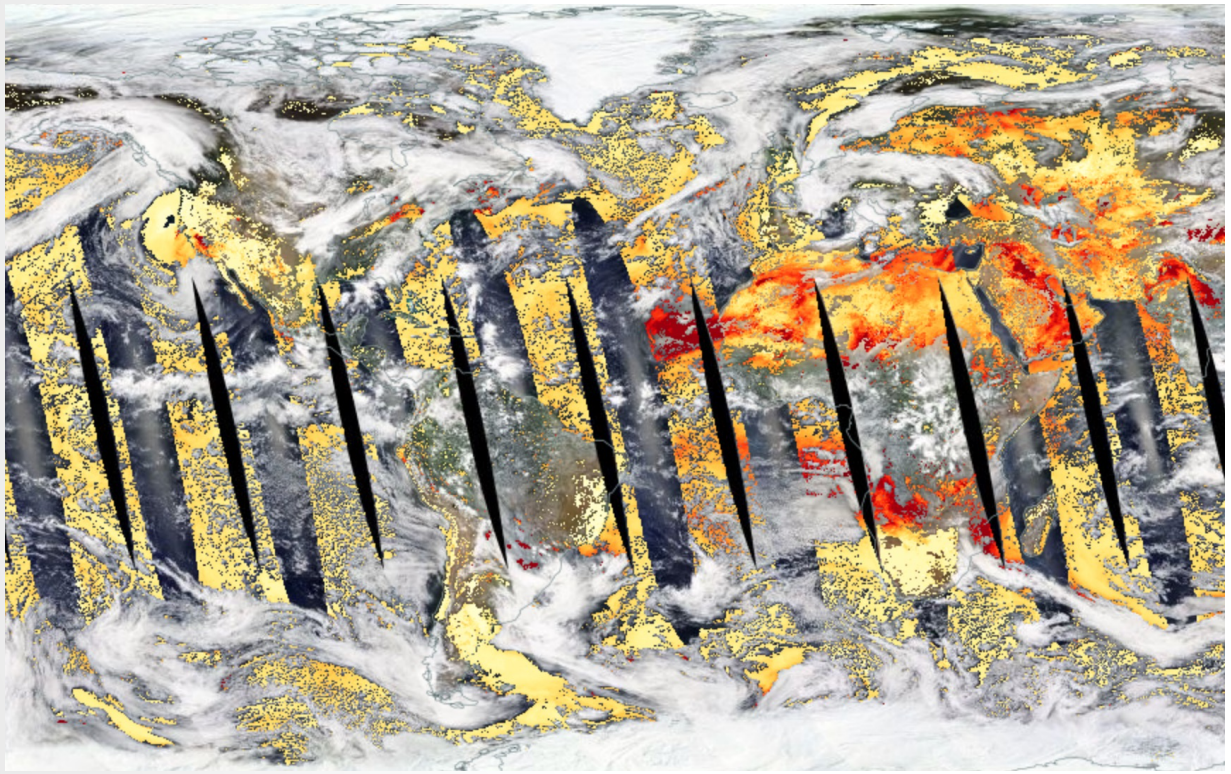
MODIS and VIIRS

MODIS		VIIRS
Aqua, Terra	Satellites	SNPP, NOAA-20, NOAA-21
1999, 2002	Launched	2011, 2017, 2022
Moderate Resolution Imaging Spectroradiometer	Instrument	Visible Infrared Imaging Radiometer Suite
405 - 14385 nm (IR, Visible)	Spectral Range	412 - 12100 nm (IR, Visible)
36	Spectral Bands	22
0.5 – 2 km pixel edge	Spatial Resolution	0.75 – 1.5 km pixel edge
1-2 Days	Global Coverage	Daily
~ 10:30, 13:30 LST	Local Overpass Time	~ 12:30, 13:30 LST

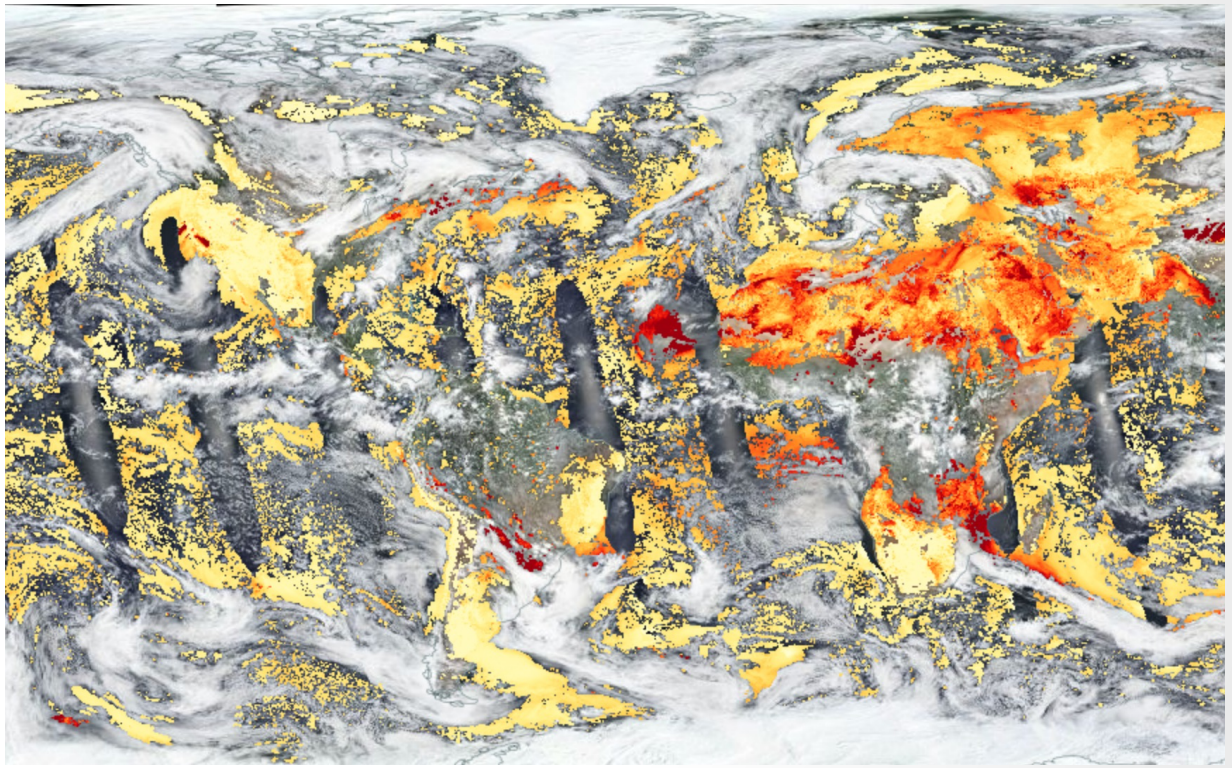
MODIS and VIIRS: Air Quality Relevant Products

MODIS		VIIRS	
True Color Image	…	True Color Image	…
Aerosol Optical Depth	MOD/MYD04_L2 (10km) MOD/MYD04_3K (3km) MCD19A2 (1km) Gridded (1°)	Aerosol Optical Depth	AERDB_L2_VIIRS (6km) AERDT_L2_VIIRS (6km) JRR-AOD_v2r3 (0.75km) Gridded (1°)
Fire Detection	MOD/MYD04A1 (1km)	Fire Detection	VNP12IMGTDL_NRT VJ114IMGTDL_NDT (0.375km)
		Smoke Detection	…
		Dust Detection	…

Aerosol Optical Depth from MODIS and VIIRS



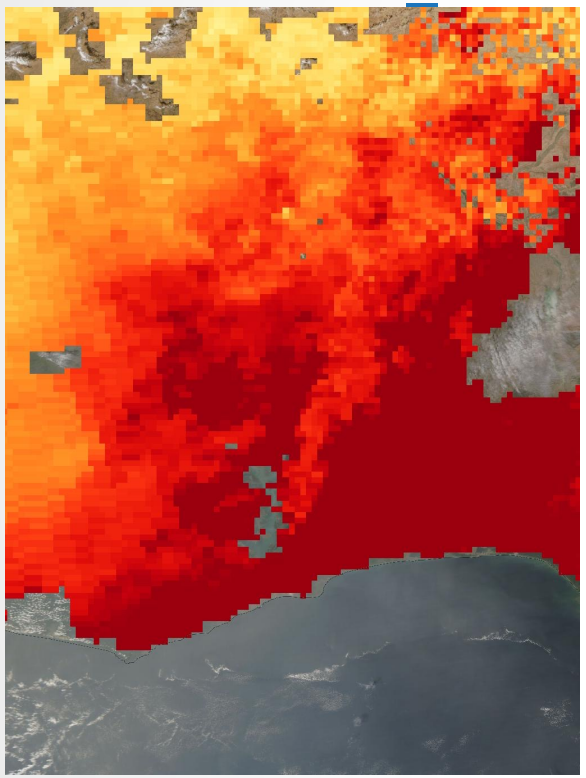
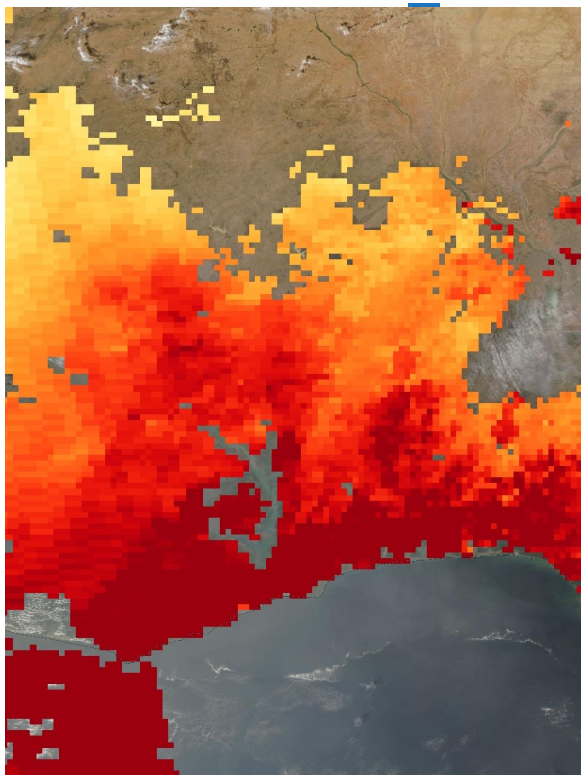
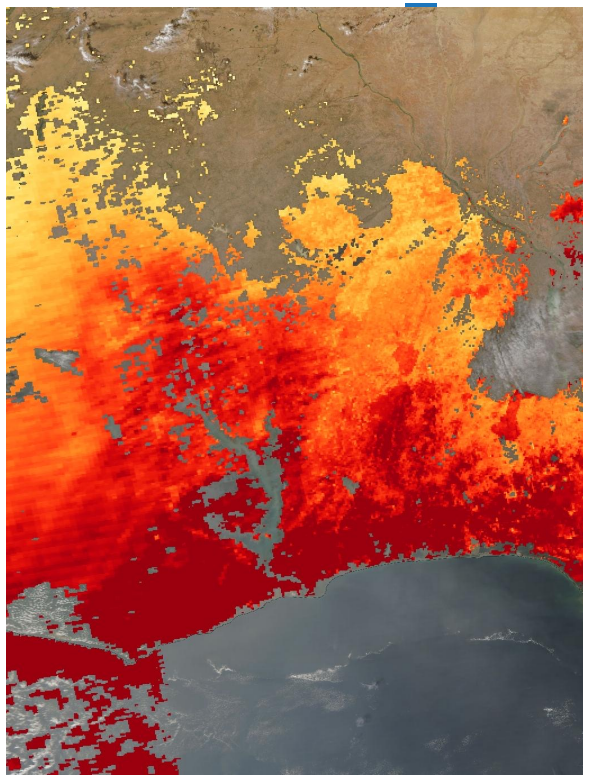
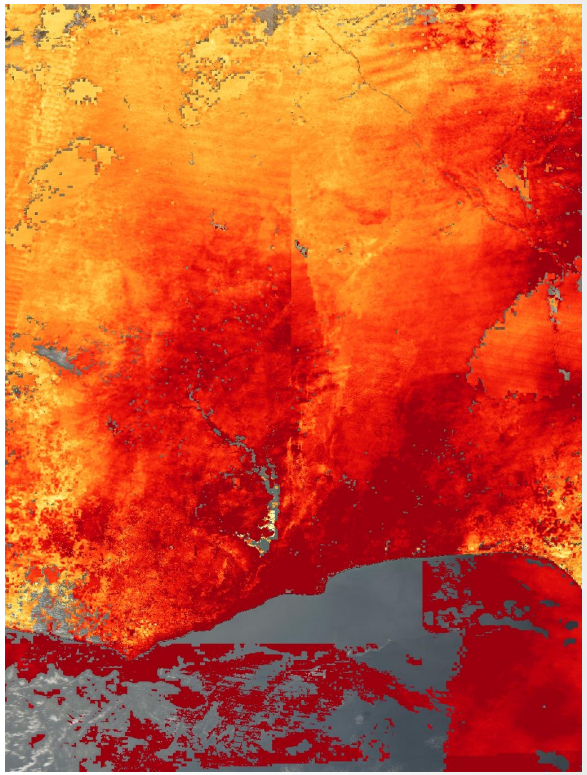
MODIS-Aqua (DB)



VIIRS-SNPP (DB)

Source: Gupta, P.; Follette-Cook, M.; Strode, S.; Malings, C. (2023). ARSET - NASA Air Quality-Focused Remote Sensing for EPA Applications. NASA Applied Remote Sensing Training Program (ARSET). http://appliedsciences.nasa.gov/join-mission/training/english/arset-nasa-air-quality-focused-remote-sensing-epa-applications

Differences in Retrieval Algorithms

Deep Blue (10km) MOD/MYD04_L2	Dark Target (10km) MOD/MYD04_L2	Dark Target (3km) MOD/MYD04_3K	MAIAC (1km) MCD19A2
			
Land only, best for bright surfaces	Land & water, best for dark surfaces	Higher resolution, issues in urban areas	Highest resolution, combine Aqua & Terra

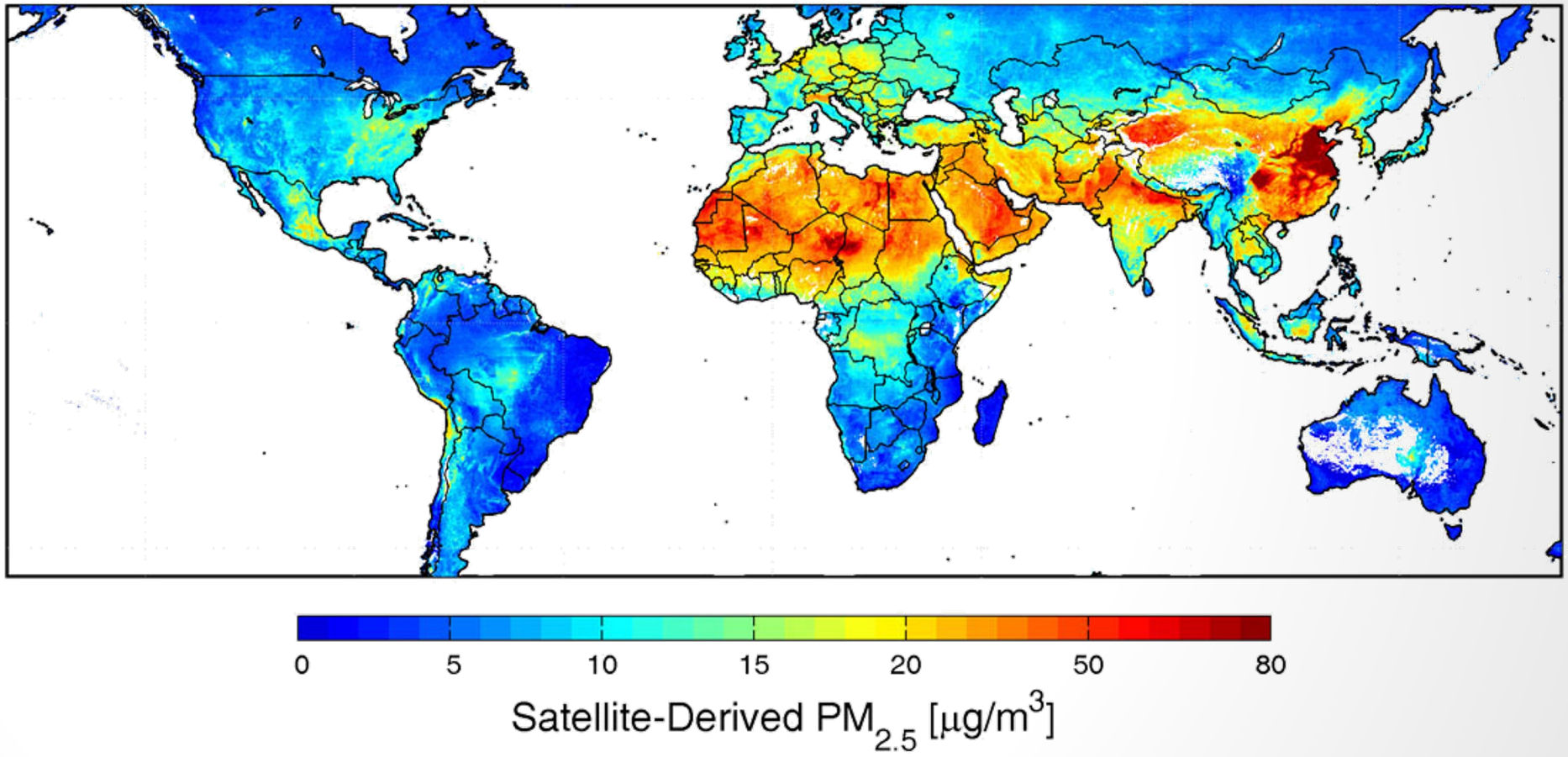
Source: Malings et al. (2023). ARSET - Satellite Data for Air Quality Environmental Justice and Equity Applications. NASA Applied Remote Sensing Training Program (ARSET). http://appliedsciences.nasa.gov/get-involved/training/english/arset-satellite-data-air-quality-environmental-justice-and-equity

Satellite-derived surface PM data products

Combine satellite data with other information (models, surface monitors) to derive high spatial resolution maps of surface concentrations (especially $PM_{2.5}$) globally and regionally.

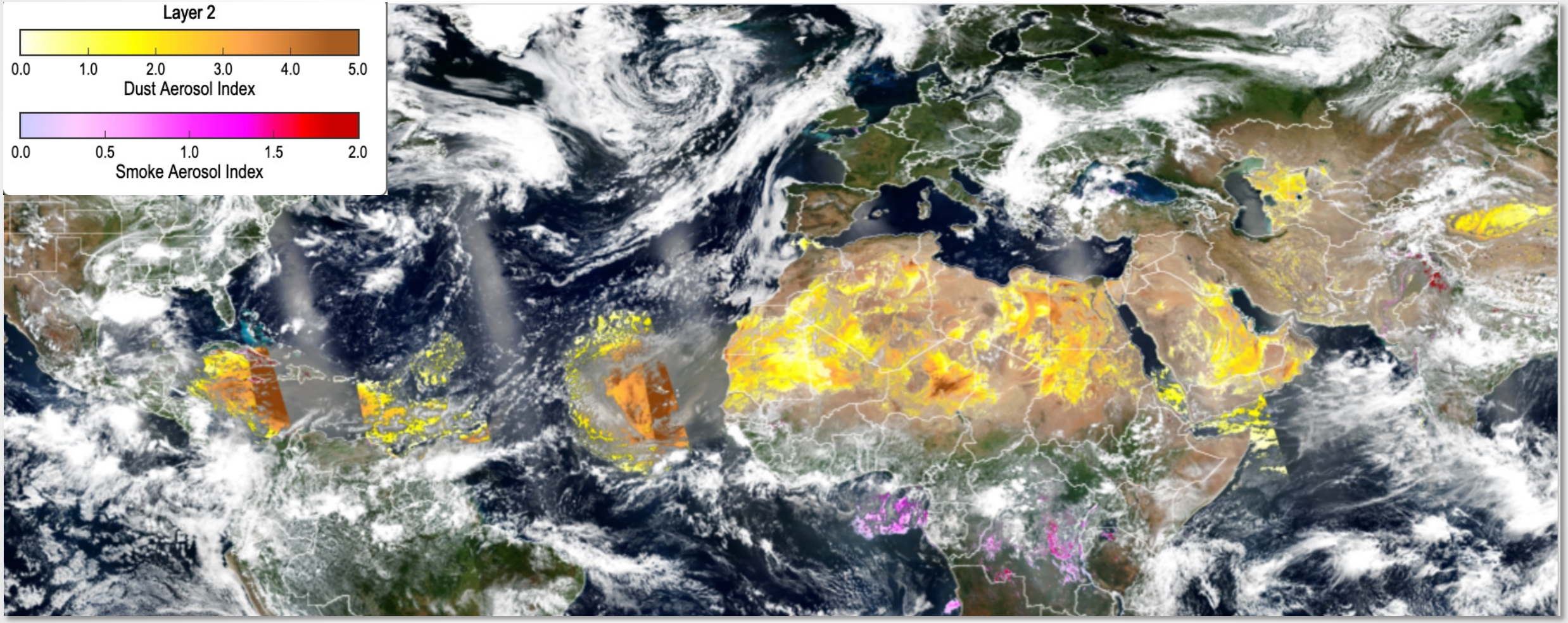
Many datasets available through NASA Socioeconomic Data and Applications Center (SEDAC).

Datasets lag significantly behind real-time.



Sources: Di et al. (2019) An ensemble-based model of $PM_{2.5}$ concentration across the contiguous US … . *Environmental International*.
van Donkelaar et al. (2021) Monthly Global Estimates of Fine Particulate Matter and Their Uncertainty. *Env. Sci. & Tech.*

VIIRS smoke and dust index to classify aerosol types



Source: NOAA JSTAR Mapper https://www.star.nesdis.noaa.gov/jpss/mapper

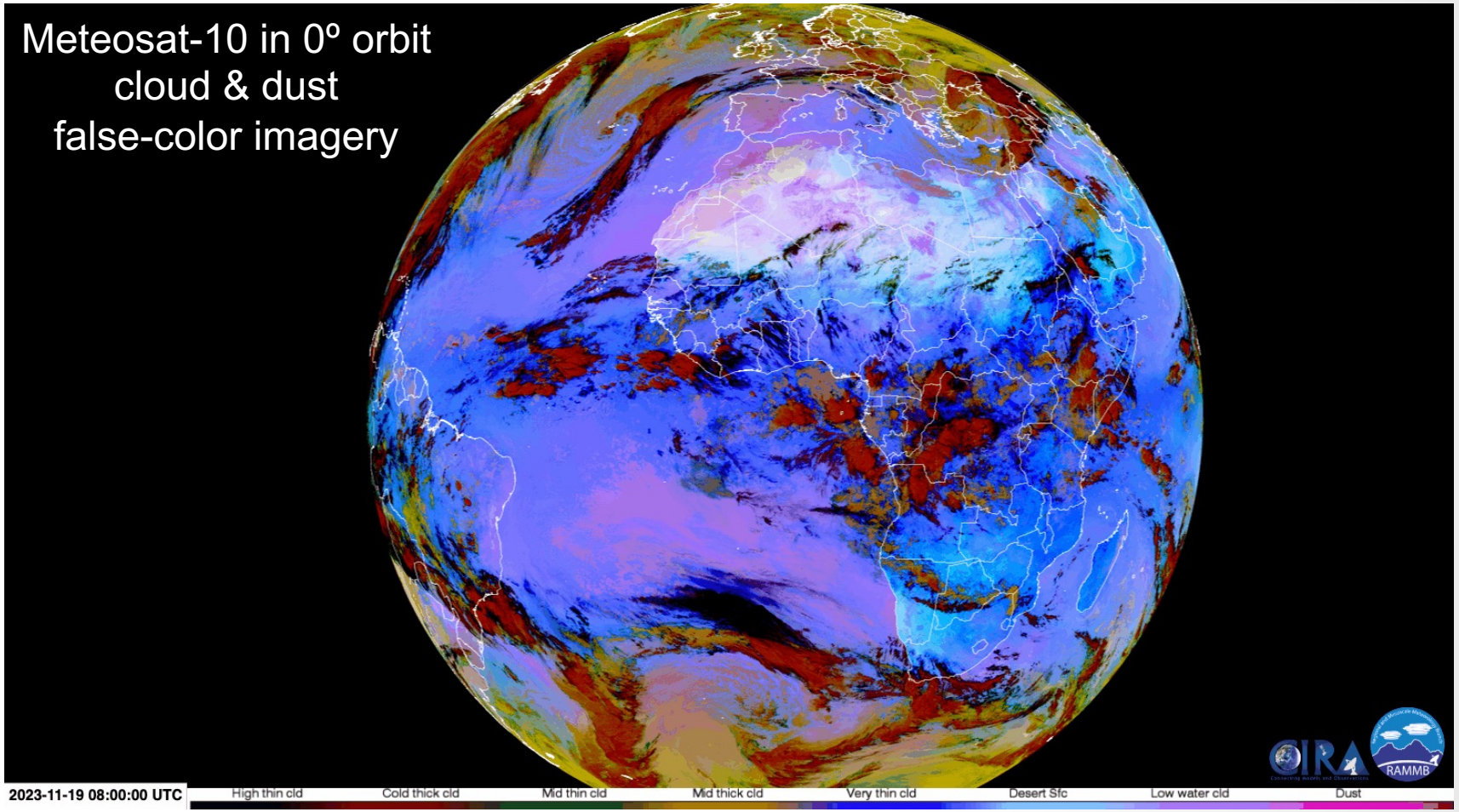
Geostationary Satellite: Meteosat-9,10,11 (ESA)

Geostationary satellites provide high temporal resolution (~15 min) full-disk imagery

Multiple satellites form a global constellation for aerosols

- GOES-16 (East US, South America)
- GOES-18 (West US, Pacific)
- Himawari-8/9 (Japan)
- GEO-KOMPSAT-2A (Korea)
- Fengyun-4 (China)
- GSAT (India)
- Meteosat-9 (Africa, India)
- Meteosat-10 (Europe, Africa)
- Meteosat-11 (Europe, Africa)

Instrument capabilities vary



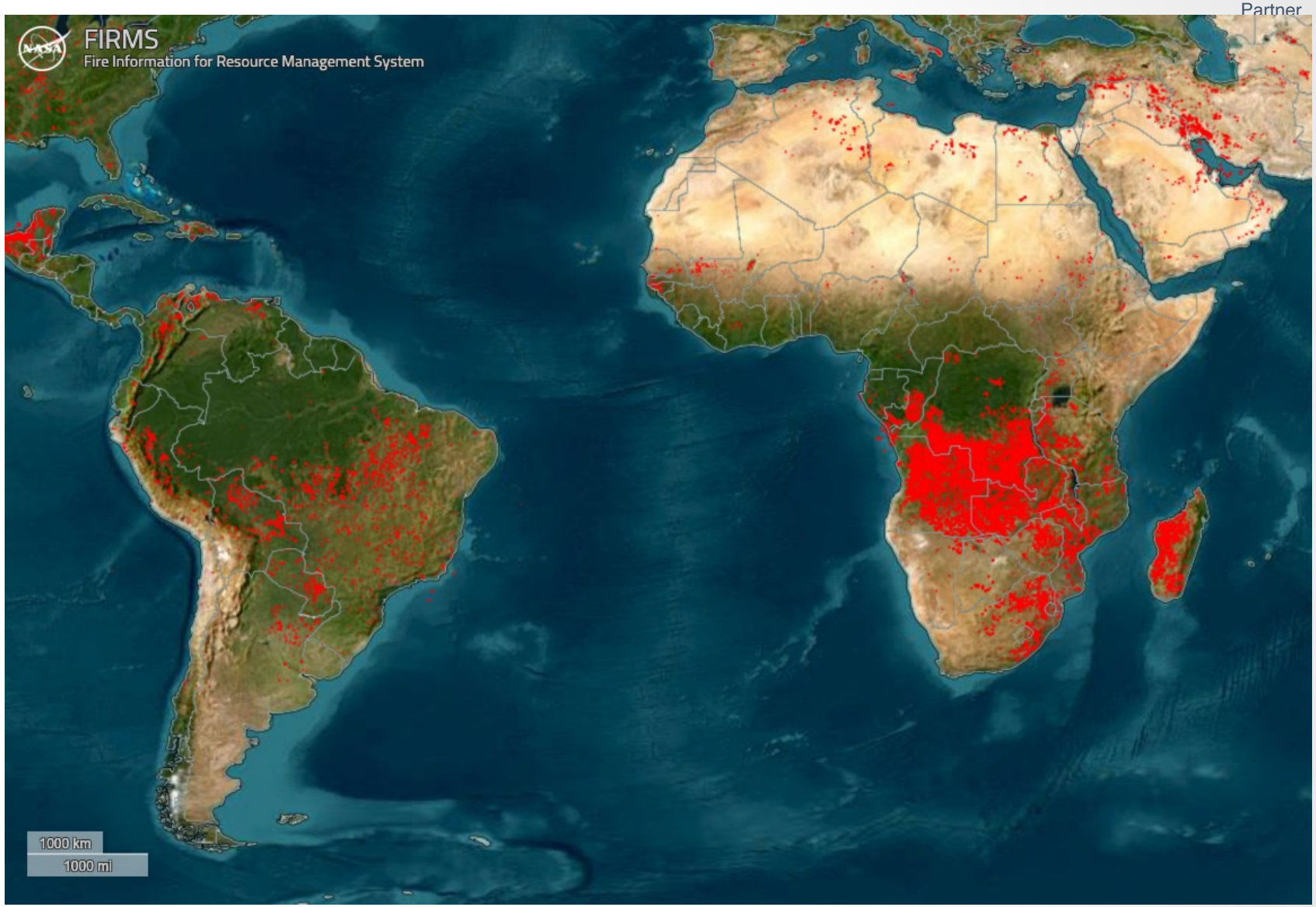
Source: Colorado State University CIRA RAMMB website https://rammb-slider.cira.colostate.edu/
EUMETSAT data product viewer https://view.eumetsat.int/productviewer

Fire Detection

Thermal Anomalies
- Detection of extreme temperatures
- Indicative of active burning
- Thick smoke can block signal
- May miss small fires

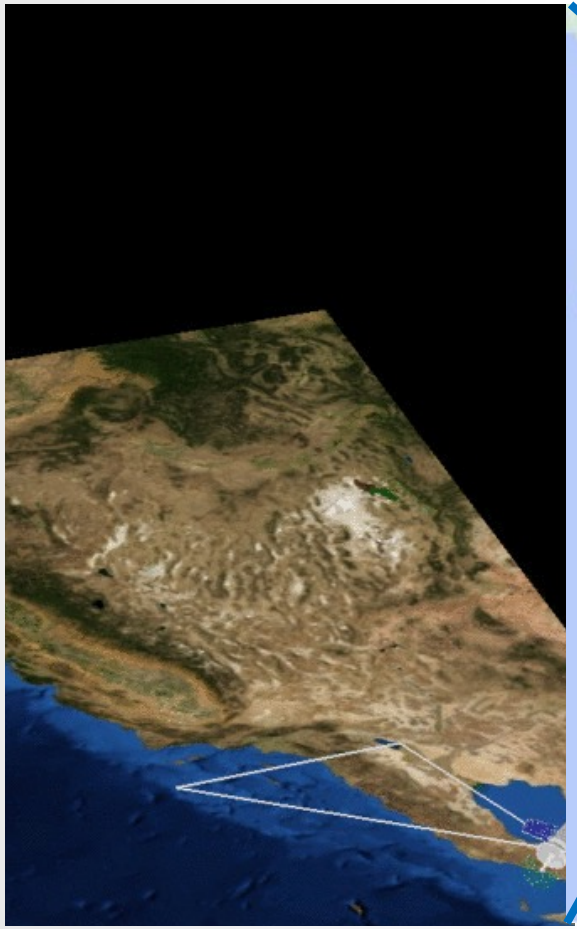
Fire Radiative Power (FRP)
- Rate of emitted radiative energy by a fire

Fire Radiative Energy (FRE)
- Time integrated FRP
- Correlation between FRE and fire emissions



Source: NASA FIRMS https://https://firms.modaps.eosdis.nasa.gov/

Multi-Angle Imager for Aerosols (MAIA)



Sources: NASA JPL MAIA Website https://maia.jpl.nasa.gov/
MAIA Early Adopters Program https://maia.jpl.nasa.gov/resources/data-and-applications/

Plankton, Aerosol, Cloud, and ocean Ecosystem (PACE)

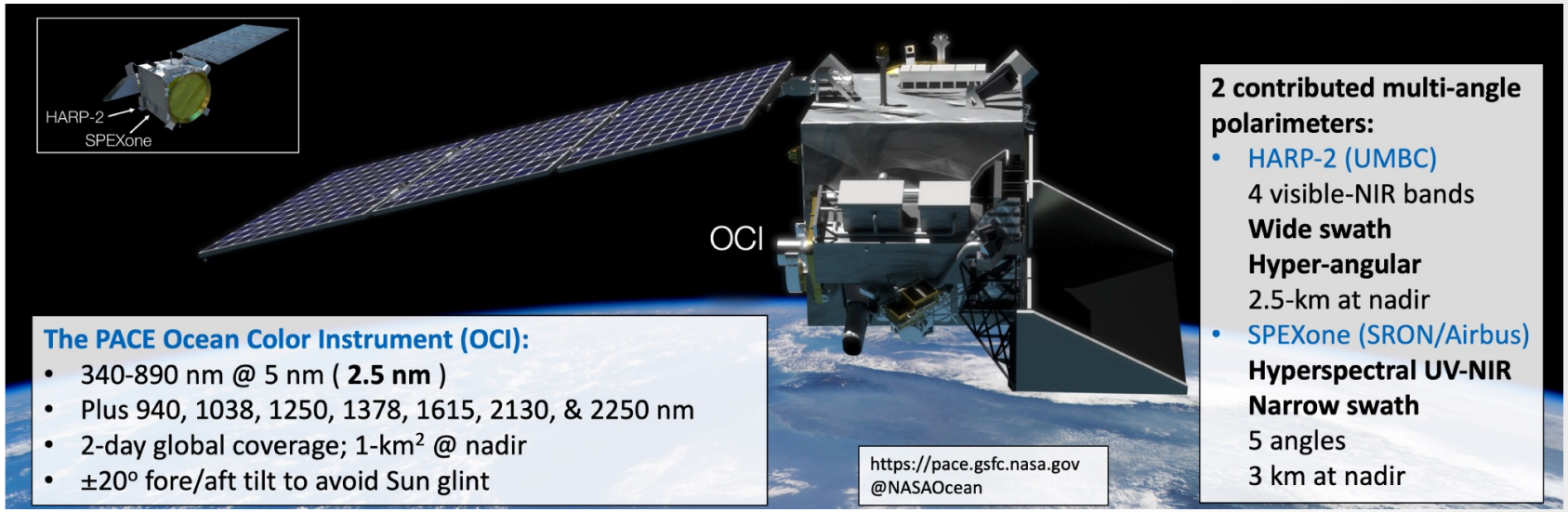
Anticipated launch January 2024.

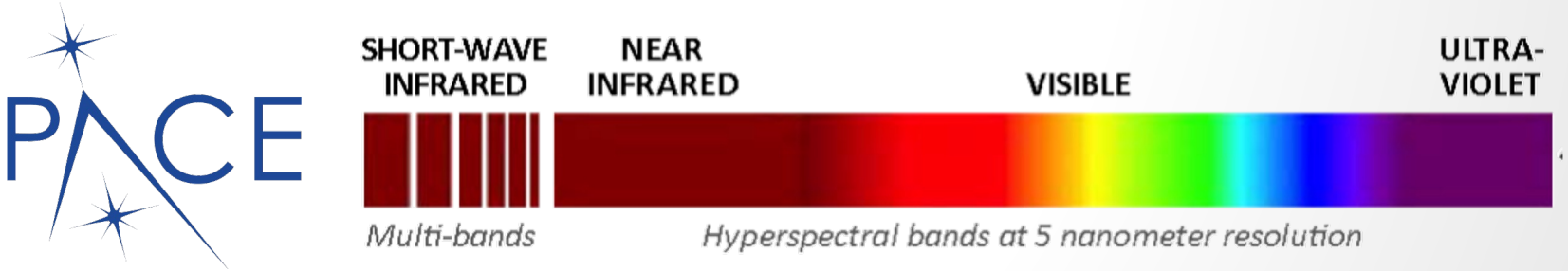
Polar-orbiting hyperspectral imager and 2 multi-angle polarimeters.

Supports applications in ocean biogeochemistry, aerosols and air quality, and clouds.

2 day global coverage.
1 km^2 spatial resolution for most data.

Anticipated air quality data products:
- Many Aerosol parameters, i.e., optical depth, size distribution, layer height, type, absorption
- NO_2
- O_3 (column)





Sources: NASA GSFC PACE Website https://pace.gsfc.nasa.gov/
PACE Early Adopters Program https://pace.oceansciences.org/app_adopters.htm

National Aeronautics and Space Administration

Partner

Satellite Data for Air Quality Trace Gases

Ozone, NO_2, Formaldehyde, SO_2, CO, and Methane from satellites

OMI and TROPOMI

OMI		TROPOMI
Aura	Satellite	Sentinel-5P
July 2004	Launched	Oct 2017
Nadir-Viewing Imaging Spectrometer	Instrument	Nadir-Viewing Imaging Spectrometer
264 – 504 nm (UV/VIS)	Spectral Range	270 nm – 2.3 μm (UV/VIS/NIR/SWIR)
0.42 – 0.63 nm	Spectral Resolution	0.55 nm
13x24 km^2 at Nadir	Spatial Resolution	5.5 x 3.5 km^2 at Nadir 7 x 28 km^2 (UV1 Band) 7 x 7 km^2 (SWIR Bands)
Daily	Global Coverage	Daily
~ 13:45 LST	Local Overpass Time	~ 13:30 LST*

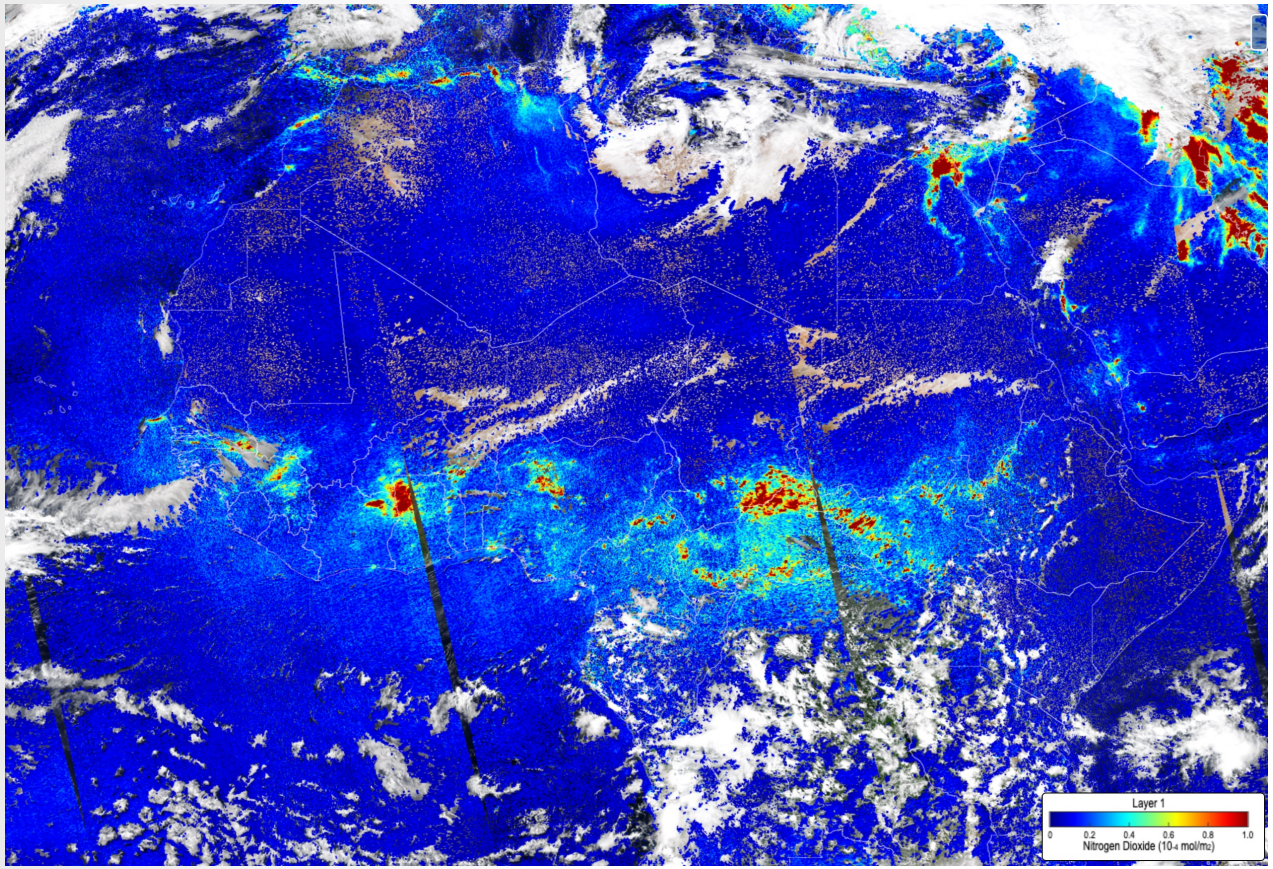
*synchronized within 5 minutes of SNPP

OMI and TROPOMI: Trace Gas Data Products

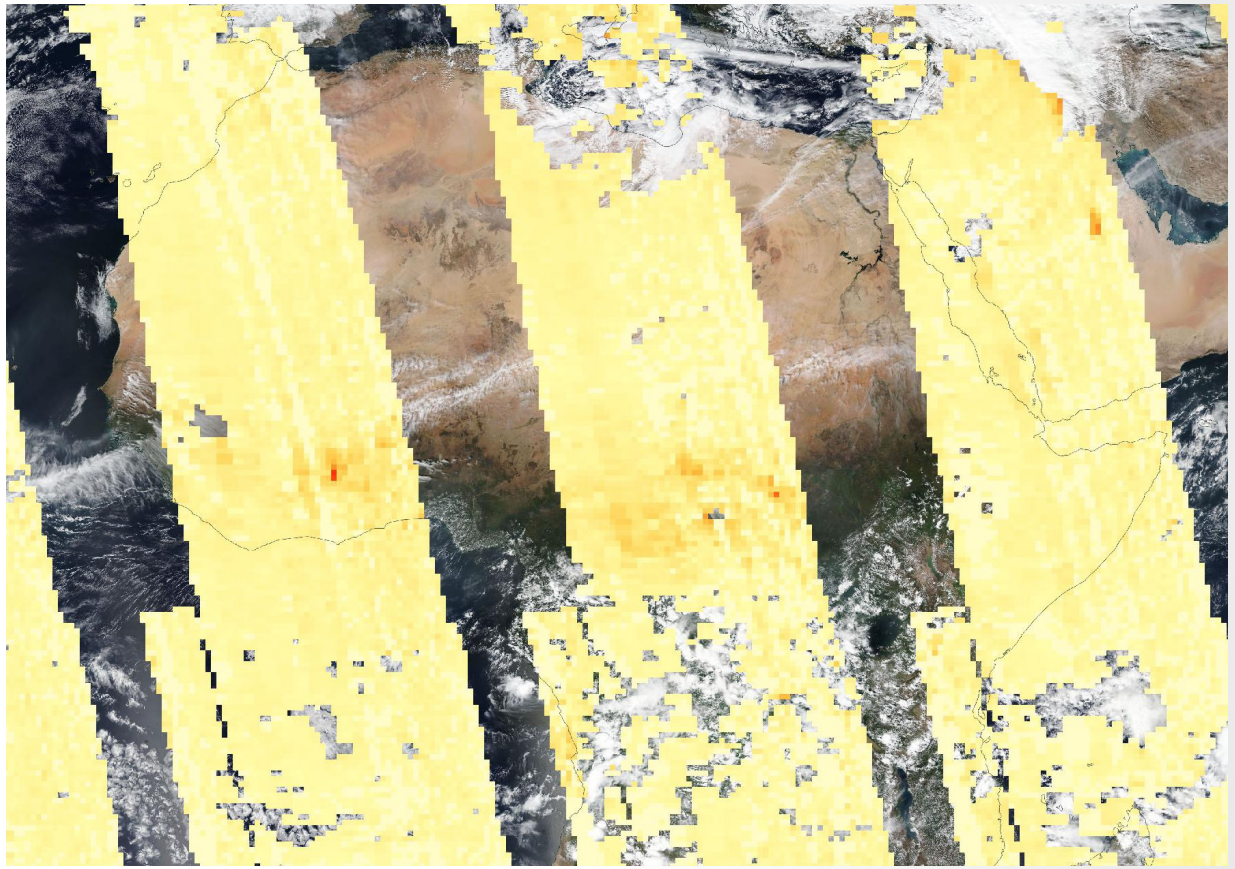
OMI		TROPOMI	
Tropospheric and Total Column NO_2	Swath, Gridded (0.25° and 0.1°)	Tropospheric and Total Column NO_2	Swath (5.5 km x 3.5km)
Total Column SO_2	Swath, Gridded (0.25°)	Total Column SO_2	Swath (5.5 x 3.5 km)
Total Column HCHO	Swath, Gridded (0.1°)	Tropospheric Column HCHO	Swath (5.5 x 3.5 km)
Tropospheric and Total Column O_3	Gridded (0.25°)	Tropospheric, Total Column O_3, Profiles	Swath (5.5 x 3.5 km)
		Carbon Monoxide (CO)	Swath (7 km x 5.5 km)
		Methane (CH_4)	Swath (7 km x 5.5 km)

TROPOspheric Monitoring Instrument (TROPOMI)

TROPOMI Tropospheric NO_2 (Launched 2017)



OMI Tropospheric NO_2 (Launched 2004)



Sources: NOAA JSTAR Mapper website https://www.star.nesdis.noaa.gov/mapper/
NASA Worldview https://worldview.earthdata.nasa.gov/

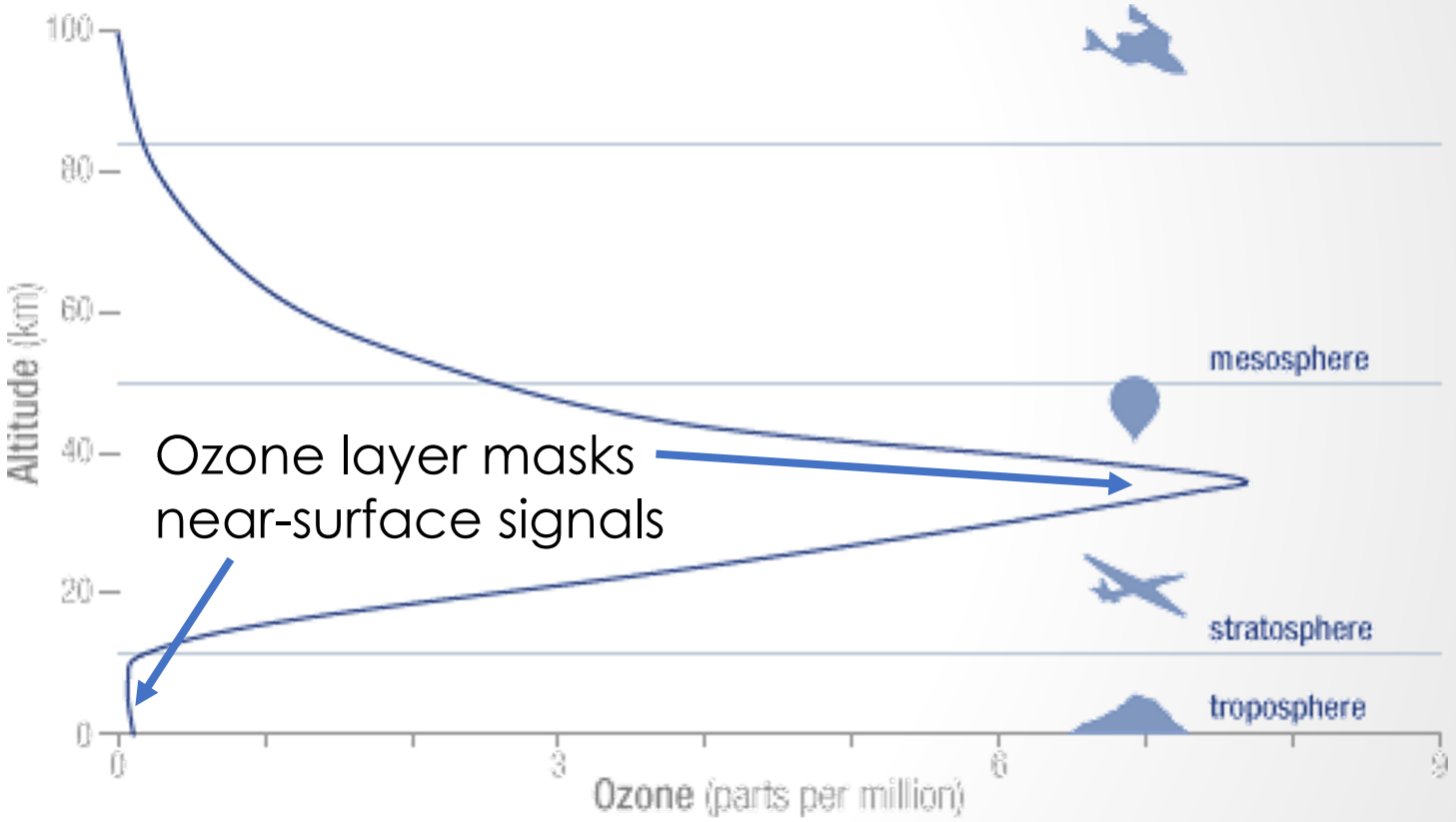
Ozone: difficult to see surface concentrations from space

Why measure O_3?

- Negative health impacts for humans, crops, and ecosystems
- Important to tropospheric chemistry

Limitations of Satellite O_3 Data

- High stratospheric concentrations mask more air-quality-relevant tropospheric concentrations
- Use of satellite Ozone is **NOT RECOMMENDED** for air quality



Source: NASA Ozone Watch

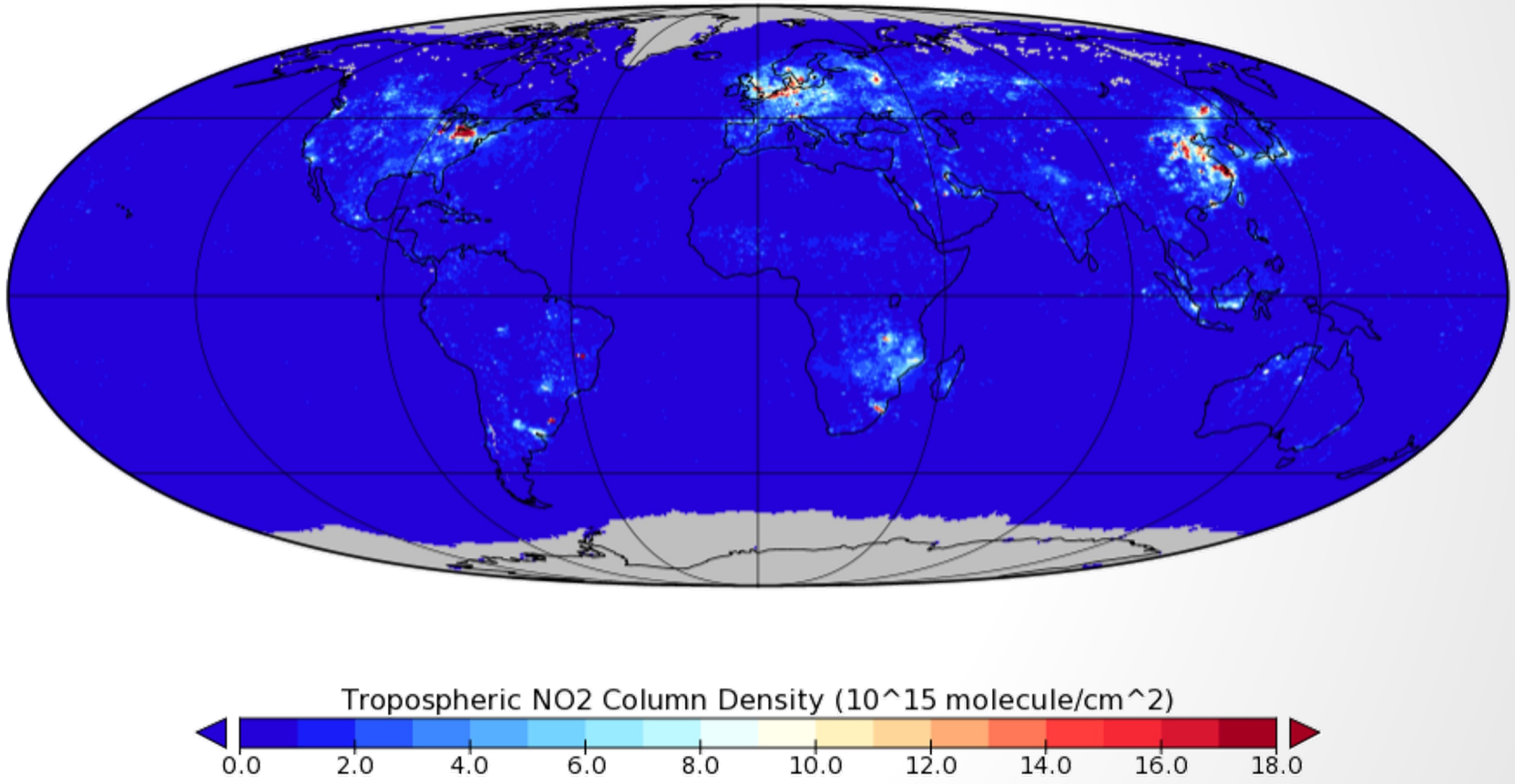
NO_2: tropospheric column matches well with surface sources

Why measure NO_2?
- health irritant
- ozone precursor
- Surface sources: fire, agricultural burning, transportation, industry, power generation
- High concentrations in the planetary boundary layer (PBL)

OMI: long data record for trends
- OMNO2 standard level 2 product
- OMNO2g gridded products

TROPOMI: high resolution
- S5P_L2__NO2____HiR
- Available from NASA Earthdata by agreement with ESA

OMNO2d Level 3 Gridded (0.25° x 0.25°) Daily Product



Source: NASA GES DISC https://disc.gsfc.nasa.gov/

Formaldehyde: VOC proxy, Ozone formation potential

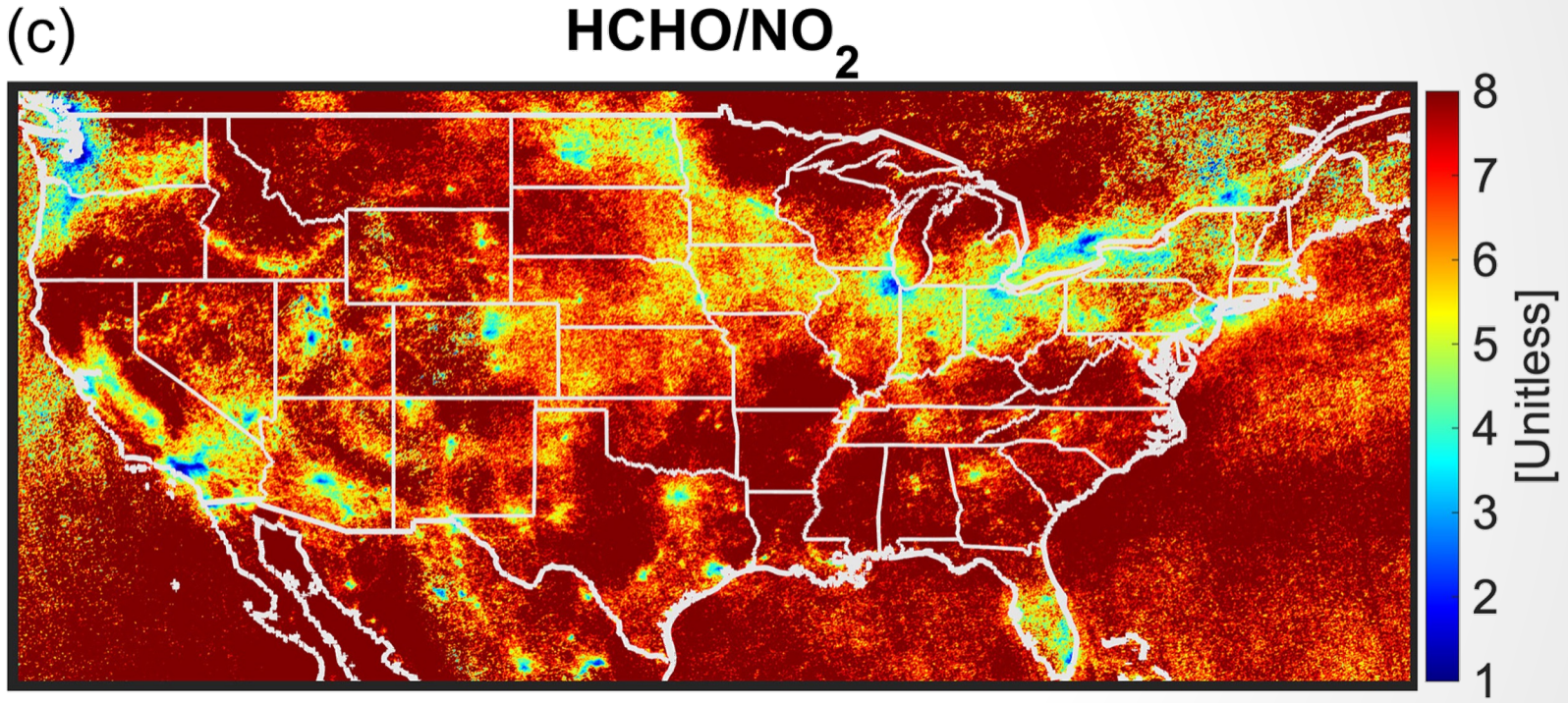
Why measure HCHO?
- Major precursor for O_3
- proxy for total VOC chemical reactivity and isoprene emissions

Using $HCHO/NO_2$ Ratios
- $HCHO/NO_2 < 1$: VOC-Limited
- $HCHO/NO_2 > 2$-4: NO_X-Limited

OMI: long data record for trends
- OMHCHO level 2 product
- OMHCHOG gridded products

TROPOMI: high resolution
- S5P_L2__HCHO___HiR_2
- Available from NASA Earthdata by agreement with ESA

Comparing HCHO and NO_2 from TROPOMI to determine Ozone Formation Potential over the US



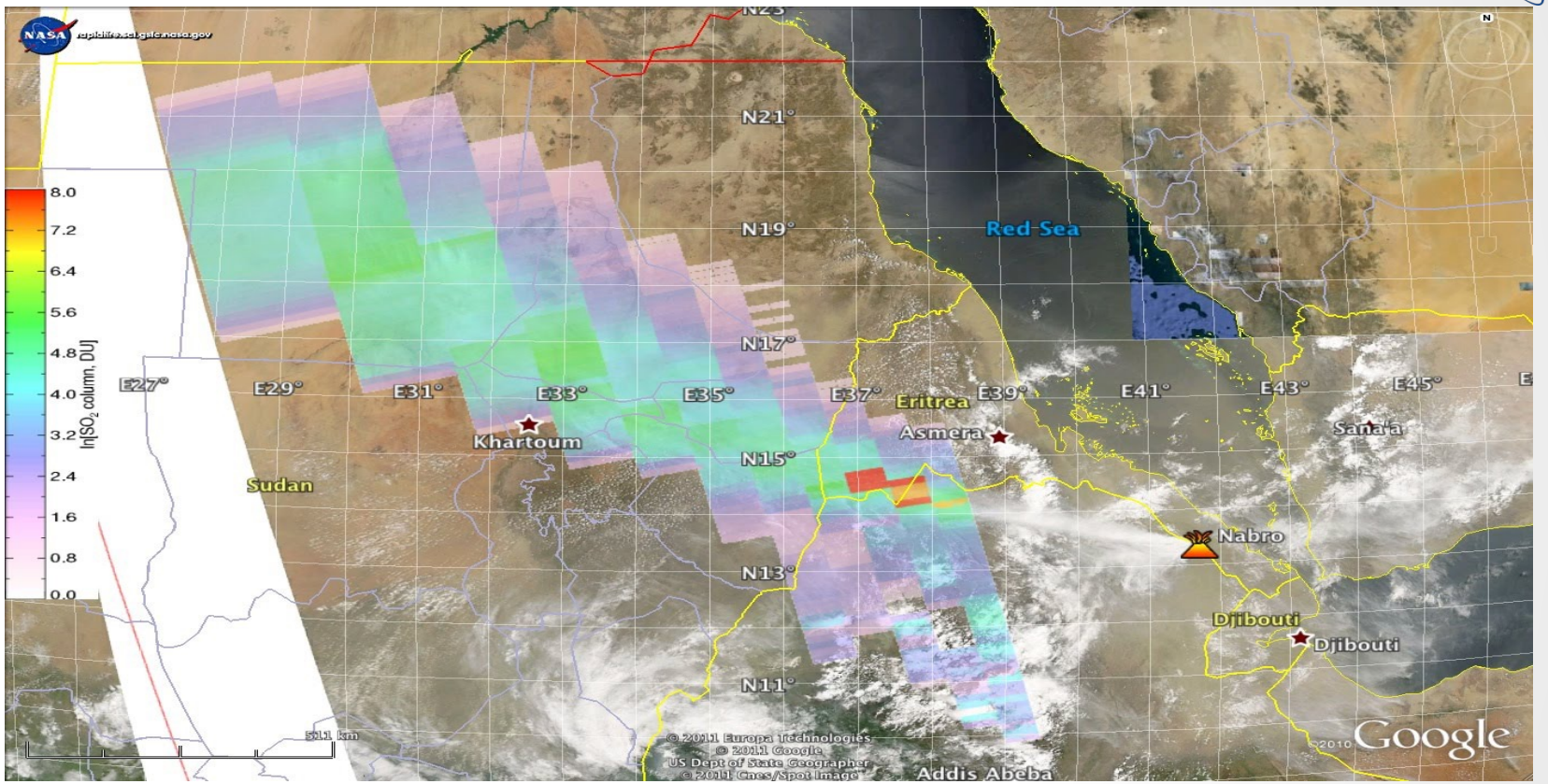
Source: Souri et al. 2023, Characterization of errors in satellite-based HCHO/NO2 tropospheric column ratios with respect to chemistry, column-to-PBL translation, spatial representation, and retrieval uncertainties. https://doi.org/10.5194/acp-23-1963-2023

SO_2: Volcanoes and other major sources are detectable

Why measure SO_2?
- SO2 has also been linked to adverse respiratory effects.
- Contributes to acid deposition
- Sources: Volcanoes, coal and oil burning

OMI: long data record for trends
- OMSO2 standard level 2 product
- OMSO2e gridded data product, assumes near-surface emissions (most relevant to air quality)

TROPOMI: high resolution
- S5P_L2__SO2____HiR
- Available from NASA Earthdata by agreement with ESA



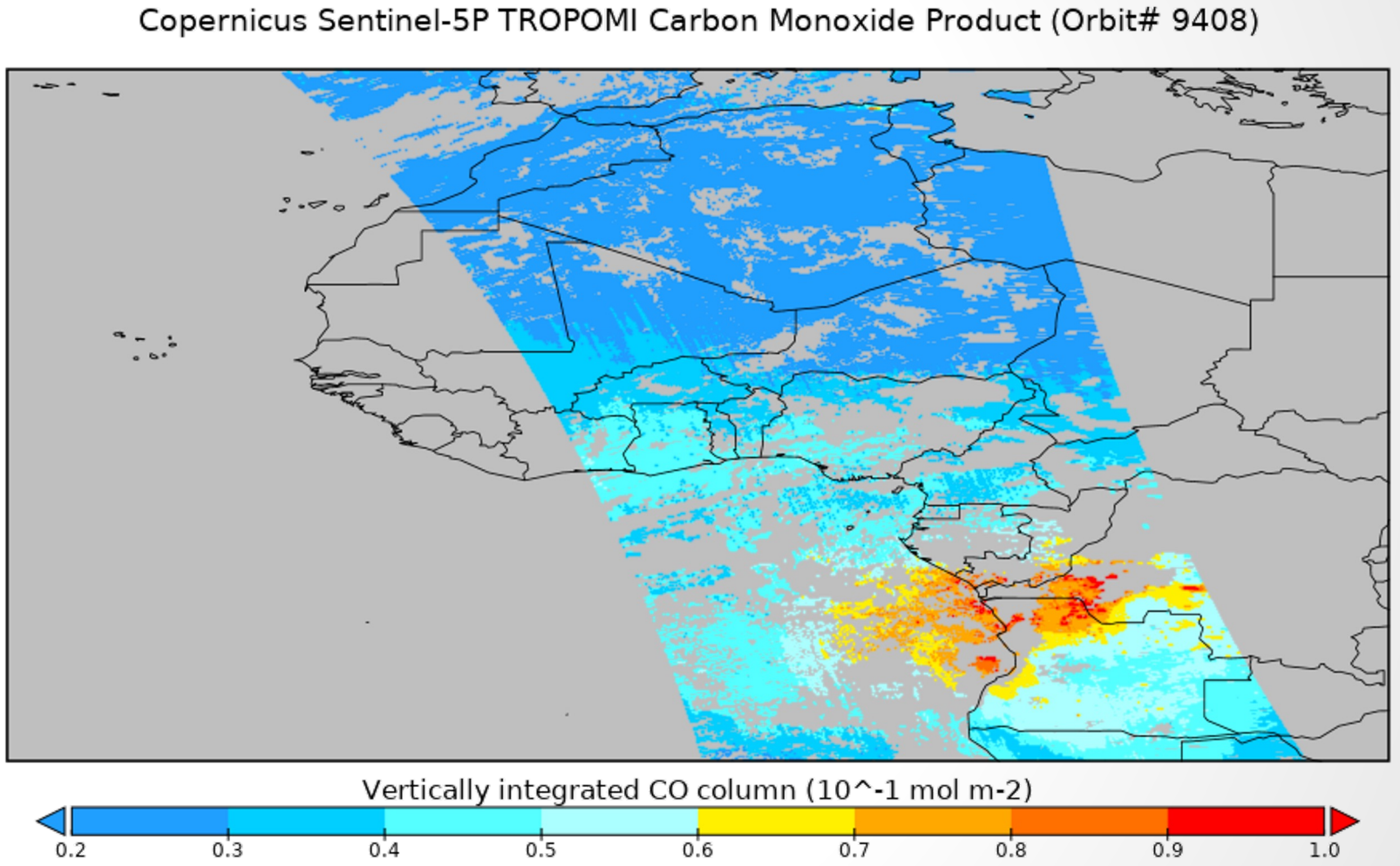
Aqua MODIS visible image of the Nabro (Eritrea) eruption on June 13, 2011, with the OMI SO_2 plume overlaid.

CO & Methane: new capabilities from TROPOMI

Why measure CO?
- Major precursor for O_3
- Relatively long lifetime (~1-2 months) makes it a useful tracer

Why measure CH4?
- Potent greenhouse gas
- “Super-emitter” point sources (natural gas leaks)
- Distributed sources (agriculture) hard to quantify from ground

TROPOMI: high resolution
- S5P_L2__CO____HiR
- S5P_L2__CH4____HiR
- Available from NASA Earthdata by agreement with ESA



Source: NASA GES DISC https://disc.gsfc.nasa.gov/

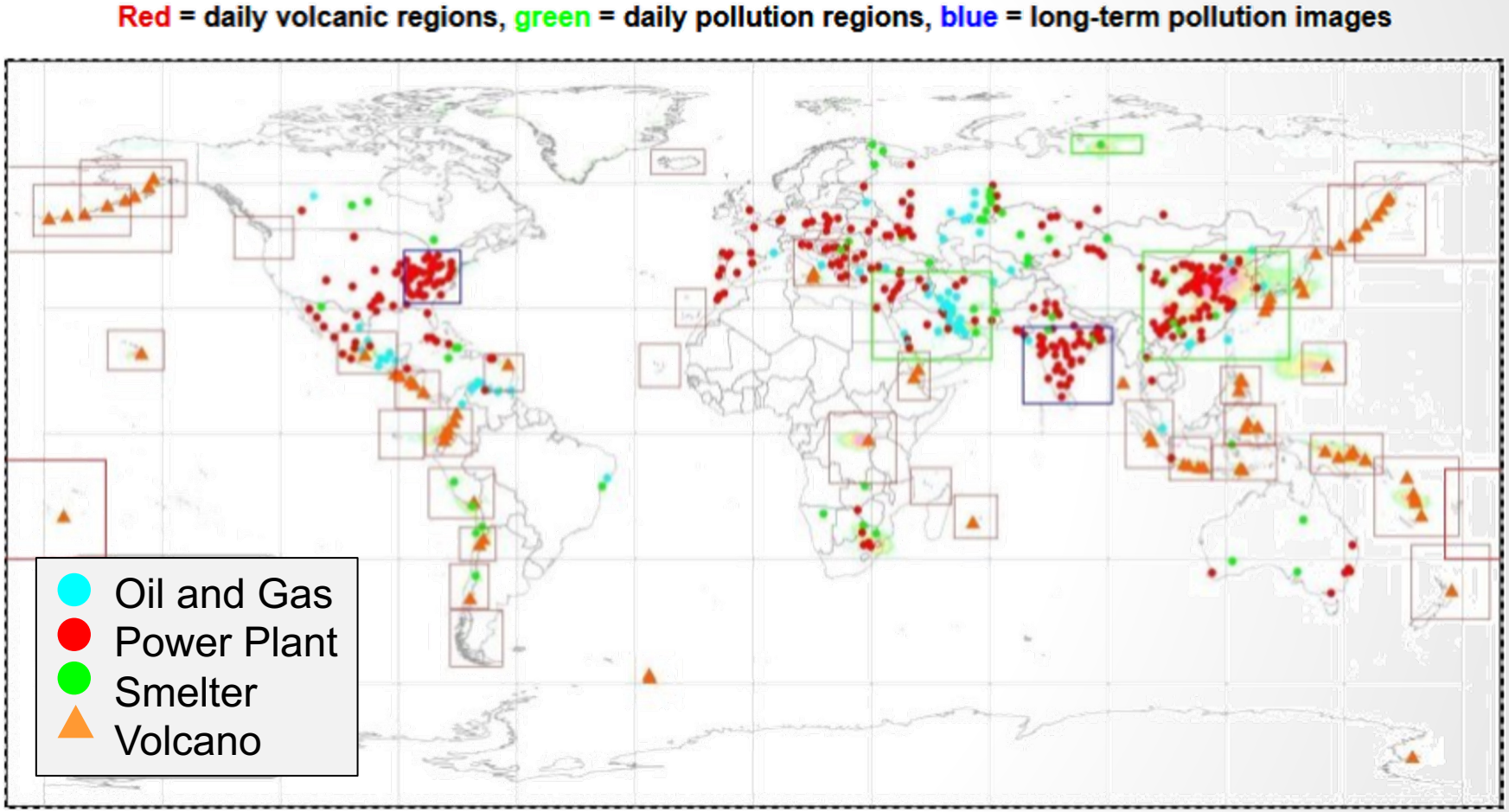
Emissions from Satellites

Developing a bottom-up emission inventory requires extensive data collection from many sources

- Costly
- Time-consuming
- May be incomplete

Satellites can estimate top-down emissions inventories

- Can keep pace with changing emissions
- May detect missing sources
- Many uncertainties in deriving emissions from satellite data



Source: NASA Global Sulfur Dioxide Monitoring Home Page https://so2.gsfc.nasa.gov/

National Aeronautics and Space Administration

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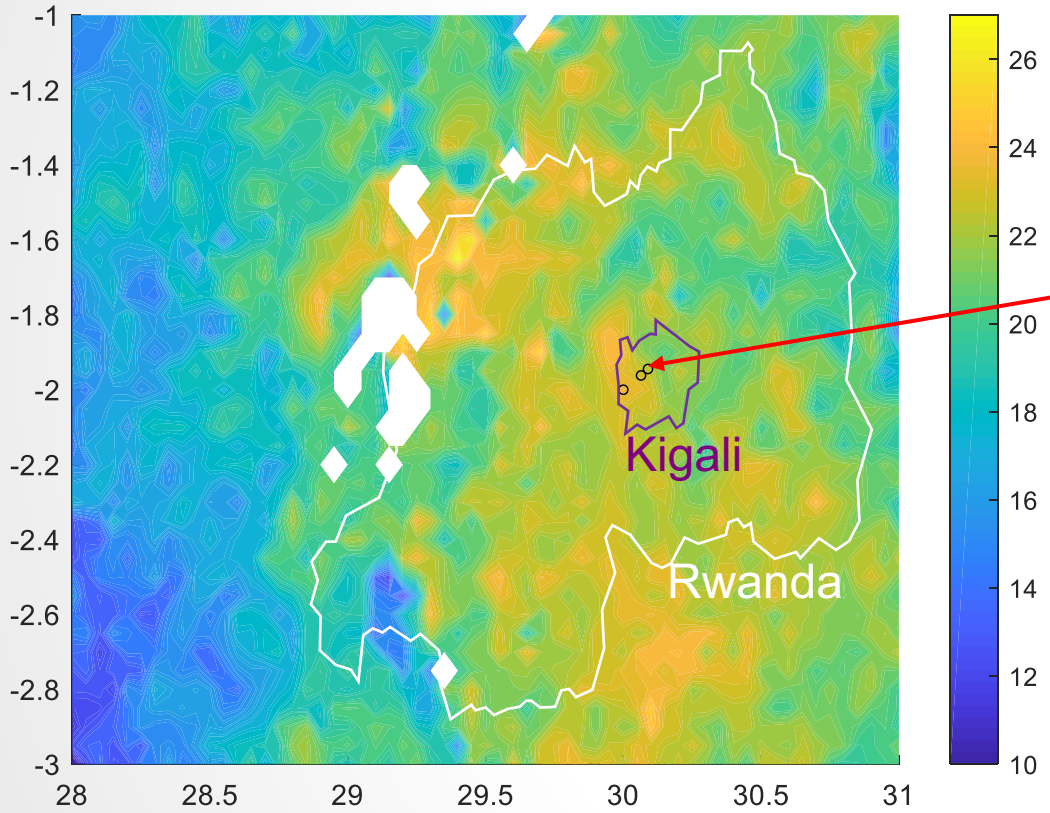
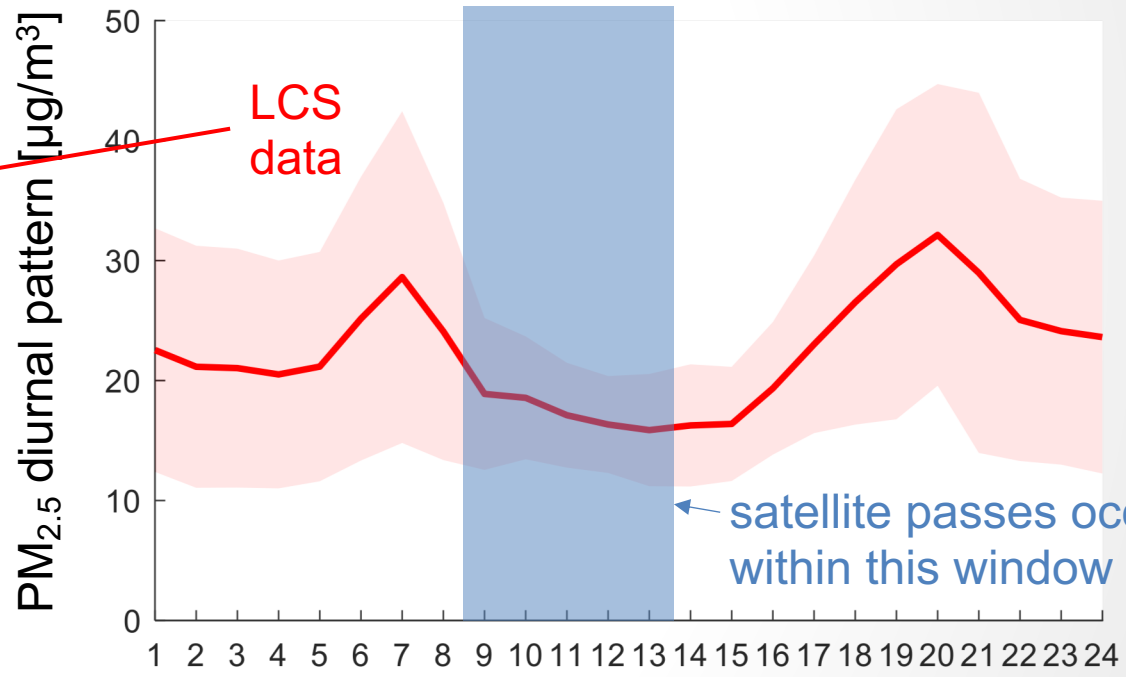
Satellite Data for Air Quality Integration with Surface Data

Satellites and low-cost sensors can be complementary

Spatial Coverage (satellite)

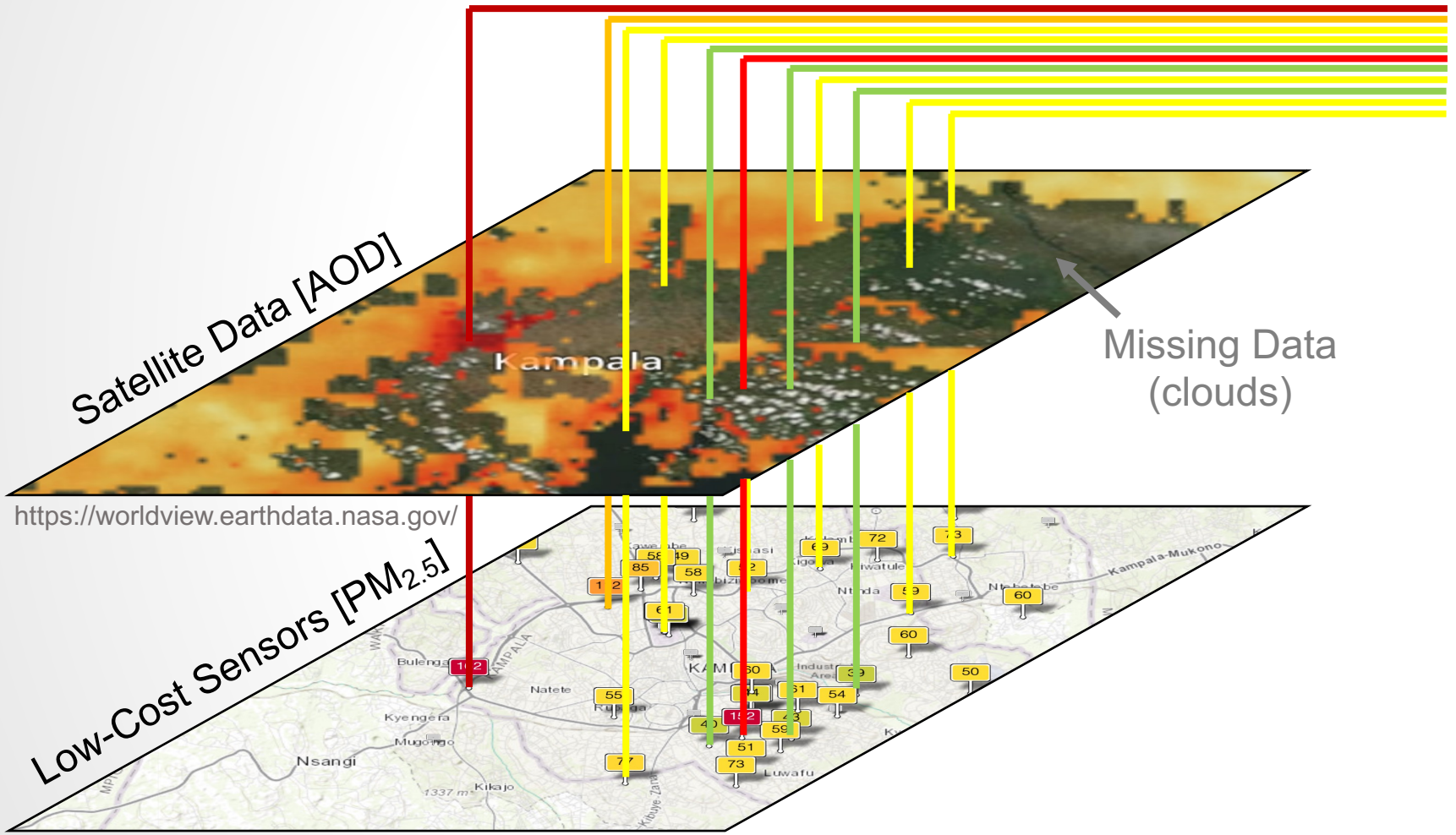


Temporal Coverage (LCS)



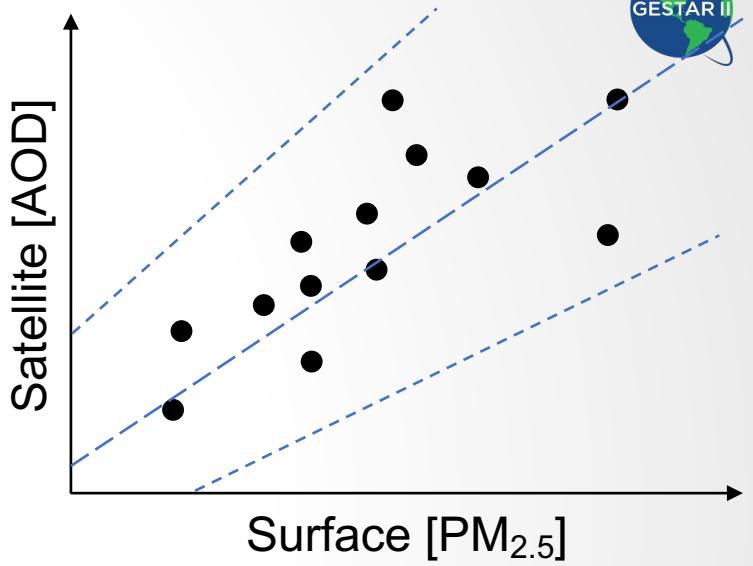
Source: Malings et al. (2020), "Application of low-cost fine particulate mass monitors to convert satellite AOD to surface concentrations in North America and Africa" *Atmospheric Measurement Techniques.* DOI: 10.5194/amt-13-3873-2020

Spatial Correlations: do satellites capture patterns?



https://worldview.earthdata.nasa.gov/

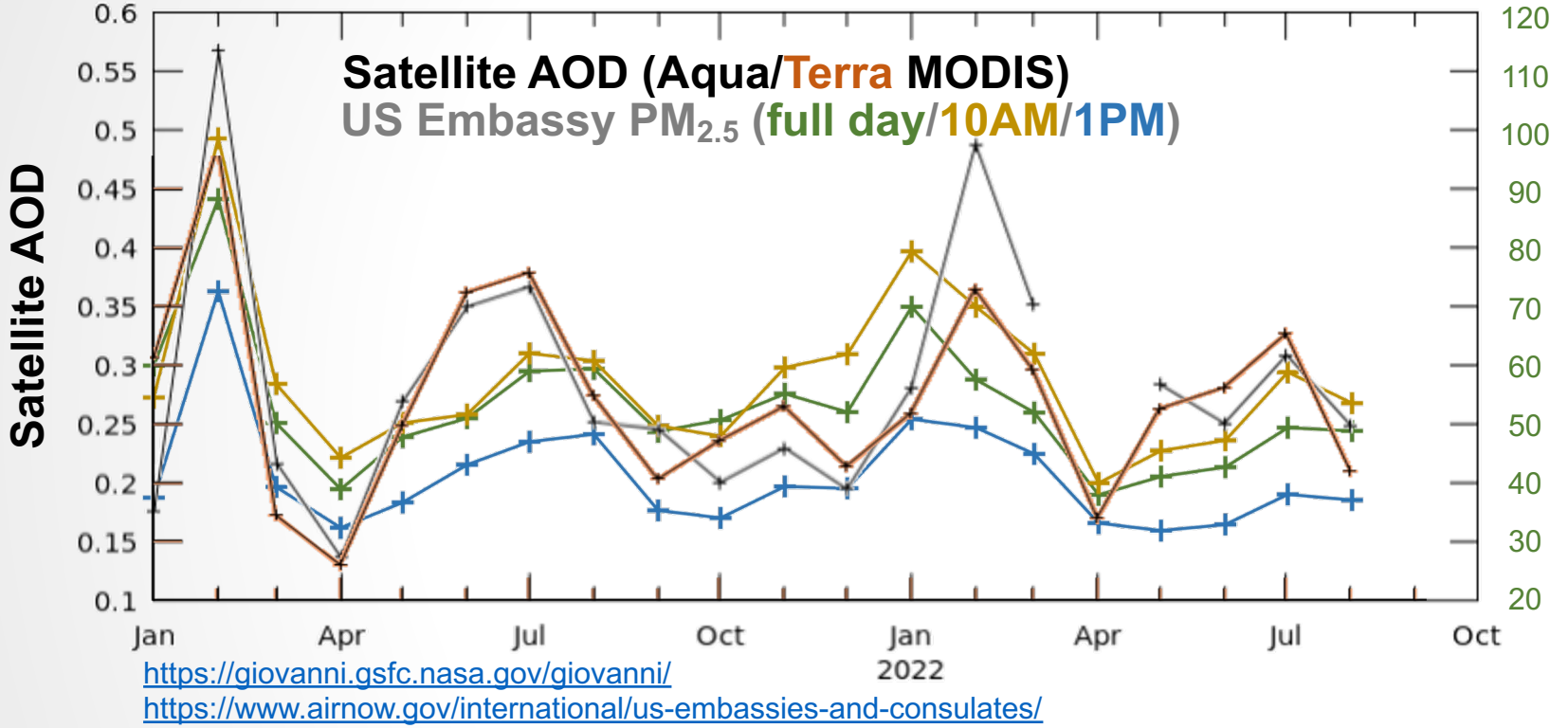
https://aqicn.org/station/network/airqo



Many confounding factors

- Averaging Time
- Time-of-day bias
- Seasonality
- Cloud Cover
- Land Use

Temporal Correlations: do satellites capture trends?



https://giovanni.gsfc.nasa.gov/giovanni/
https://www.airnow.gov/international/us-embassies-and-consulates/

Example: trends in Kampala (0-1N,32-33E) for 1+ year

Trends at US embassy may not represent city-wide trends

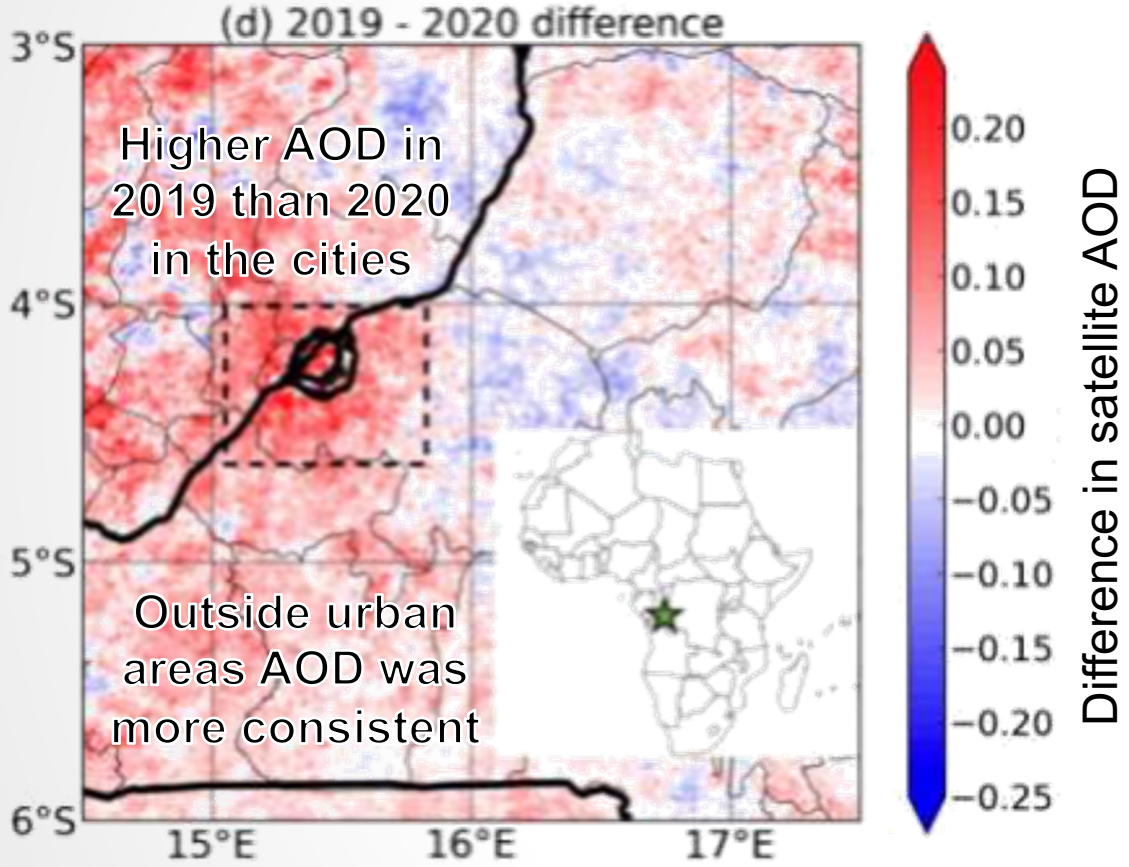
Comparing at different times of day

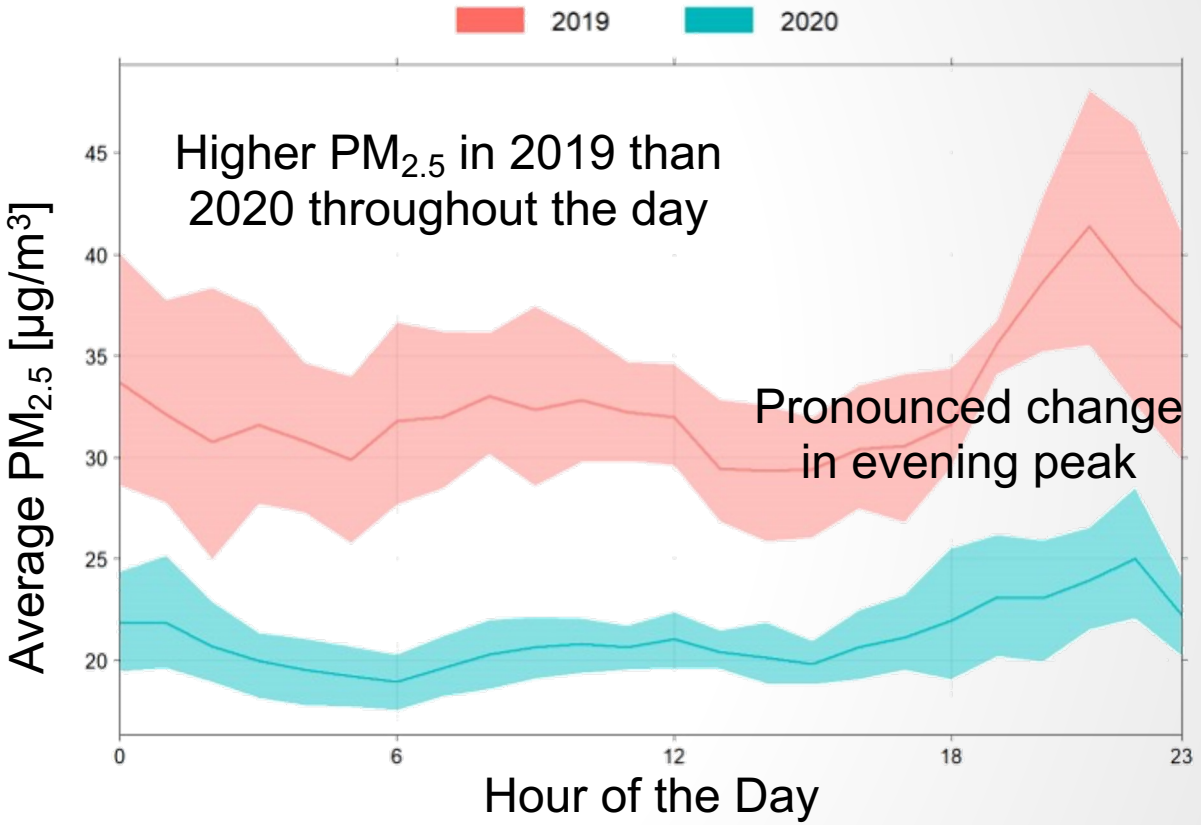
Full Day Average
Morning ↔ **Terra**
Afternoon ↔ **Aqua**

Many confounding factors

- Averaging Area
- Averaging Time
- Time-of-day bias
- Seasonality
- Cloud Cover

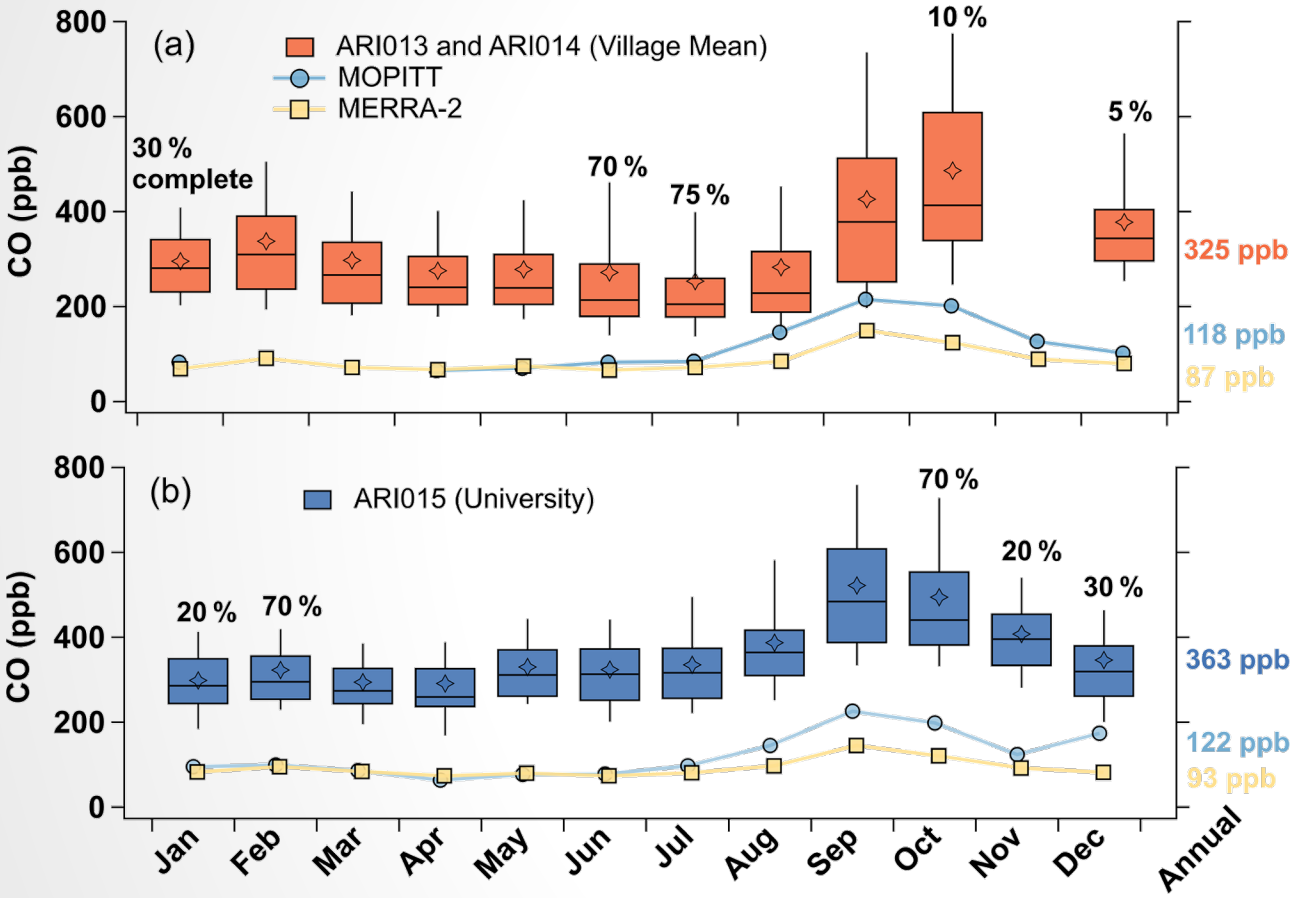
Qualitative: COVID-19 impact in Brazzaville & Kinshasa





Source: McFarlane et al. (2021). "First Measurements of Ambient $PM_{2.5}$ in Kinshasa, Democratic Republic of Congo and Brazzaville, Republic of Congo Using Field-calibrated Low-cost Sensors." Aerosol and Air Quality Research, 21. DOI: 10.4209/aaqr.200619.

Quantitative Comparison & Validation: CO in Malawi



ARISENSE Low-Cost Sensor Package
MOPITT Satellite
MERRA-2 Reanalysis (Model + Satellite)

Data sources agree on trends
- Higher CO in urban than rural areas
- Higher CO in burning season (Aug-Nov)

Data sources disagree on magnitudes
- Satellite ~30% higher than model during peaks
- LCS 2-4x higher than model or satellite

Numerous confounding factors
- No reference for region-specific LCS calibration
- Hyper-local sources (cooking, traffic)
- Once-daily MOPITT satellite passes

Source: Bittner et al. (2022) “Performance characterization of low-cost air quality sensors for off-grid deployment in rural Malawi.” Atmospheric Measurement Techniques. 15:11. DOI: 10.5194/amt-15-3353-2022

National Aeronautics and Space Administration

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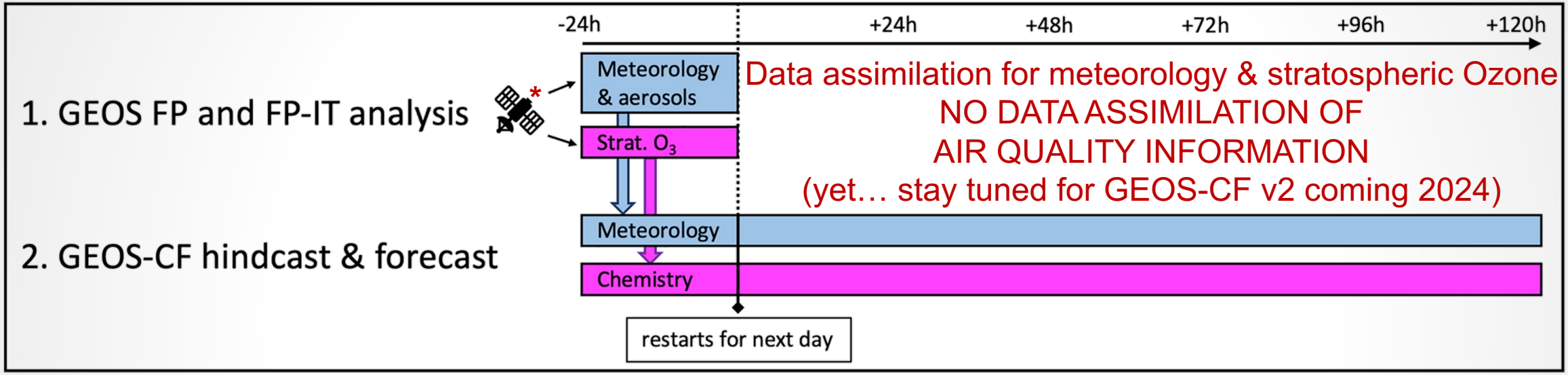
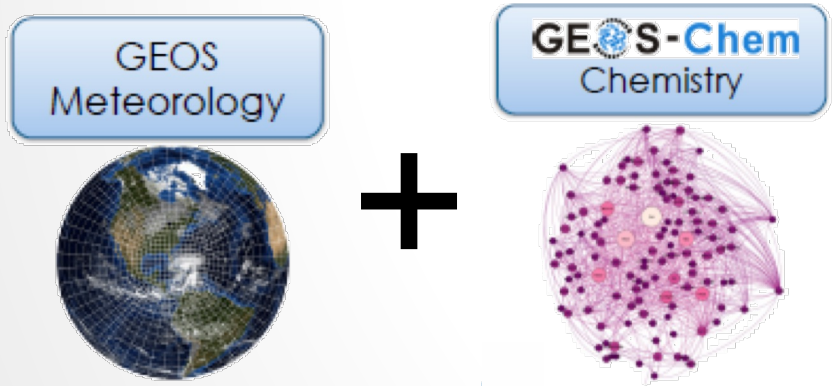
Satellite Data for Air Quality Integration with Global Models

GEOS-CF: NASA global air quality forecast model





- Combine GEOS meteorology with GEOS-Chem chemistry
- 250 chemical species
- Hourly temporal resolution
- 0.25 degree (25 km) spatial resolution
- Global coverage
- Daily 1-day replay and 5-day forecast

Source: Keller, C., et al. (2021) "Description of the NASA GEOS Composition Forecast Modeling System GEOS-CF v1.0". *Journal of Advances in Modeling Earth Systems*, 13:4. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020MS002413

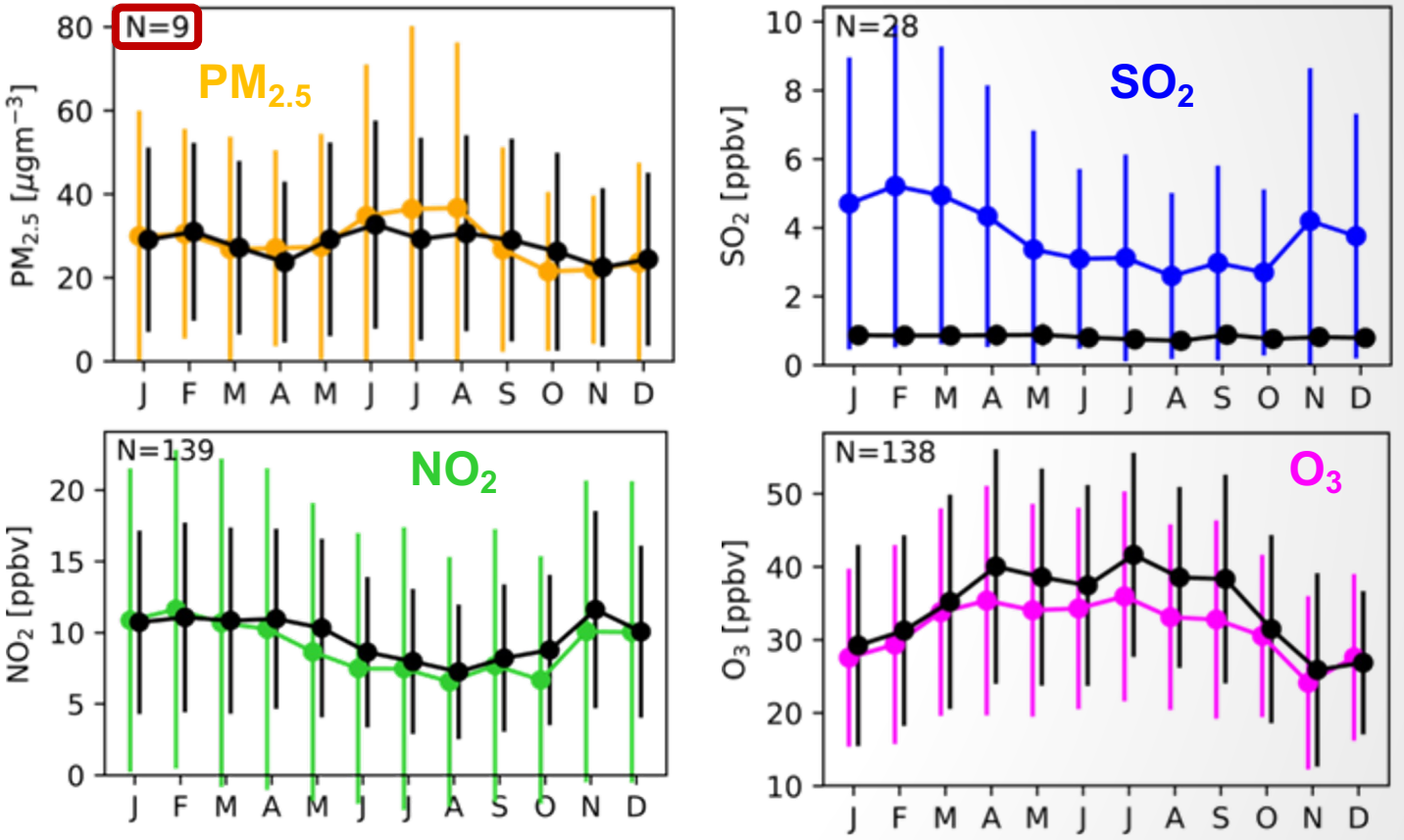
GEOS-CF performance evaluation

In general, GEOS-CF estimates and forecasts agree well with ground-based data for air quality relevant quantities.

HOWEVER:

- Agreement can vary annually, seasonally and by region.
- There can be high bias at individual locations due to local impacts.
- Many regions have limited ground data for verification.
- Some pollutants are not well represented yet (SO_2 is biased high globally).

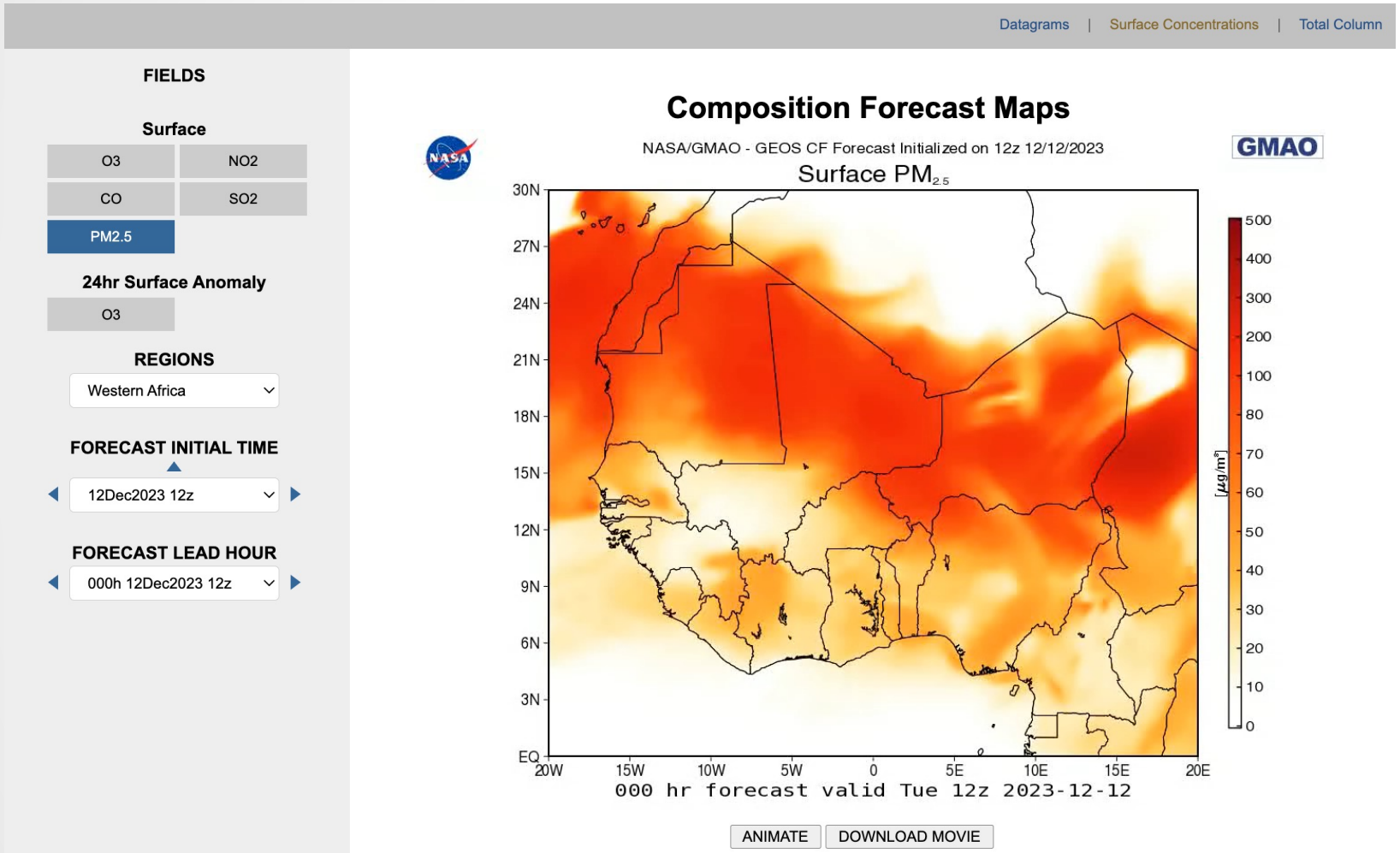
Monthly average concentrations at sites in Africa



GEOS ground data

Source: Keller, C., et al. (2021) "Description of the NASA GEOS Composition Forecast Modeling System GEOS-CF v1.0". *Journal of Advances in Modeling Earth Systems*, 13:4. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020MS002413

Visualizing GEOS-CF forecasts in GMAO FLUID



The GMAO FLUID website provides access to visualizations of GMAO data products, including

GEOS-CF replay and forecast surface concentration maps and animations are available globally and for regions.

Pre-generated “datagrams” for world cities depict the forecast time series and details.

Custom interfaces are often developed to support NASA airborne campaigns.

Source: GMAO FLUID for GEOS-CF https://fluid.nccs.nasa.gov/cf/

GEOS-CF interactive map and forecast datagrams

Available Products

NO2

O3

PM2.5

Geotiff Forecast Selection

Forecast Date

20231212

Forecast Time

1230

Colormap Options

plasma

Quick Stations

NATIONAL

--Select a Station--

WORLD

--Select a Station--

AERONET

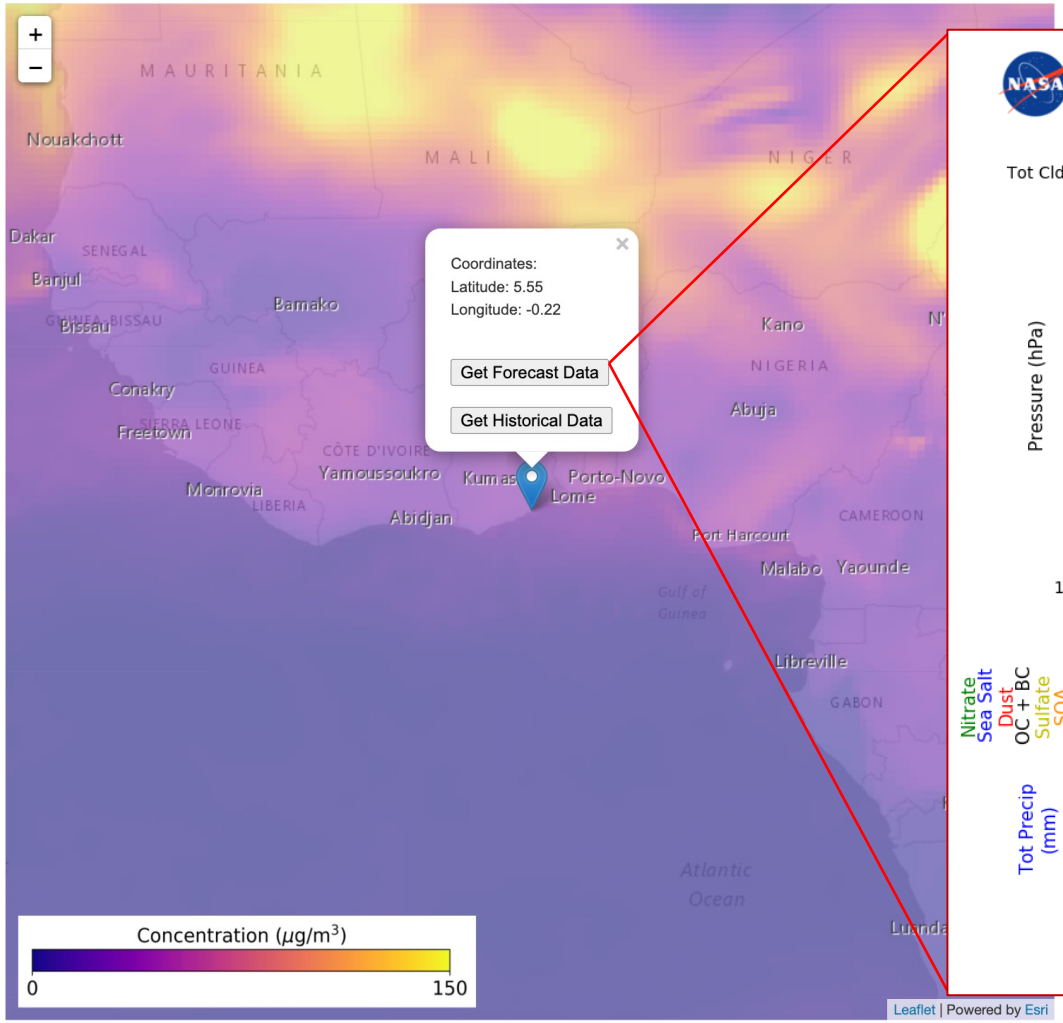
--Select a Station--

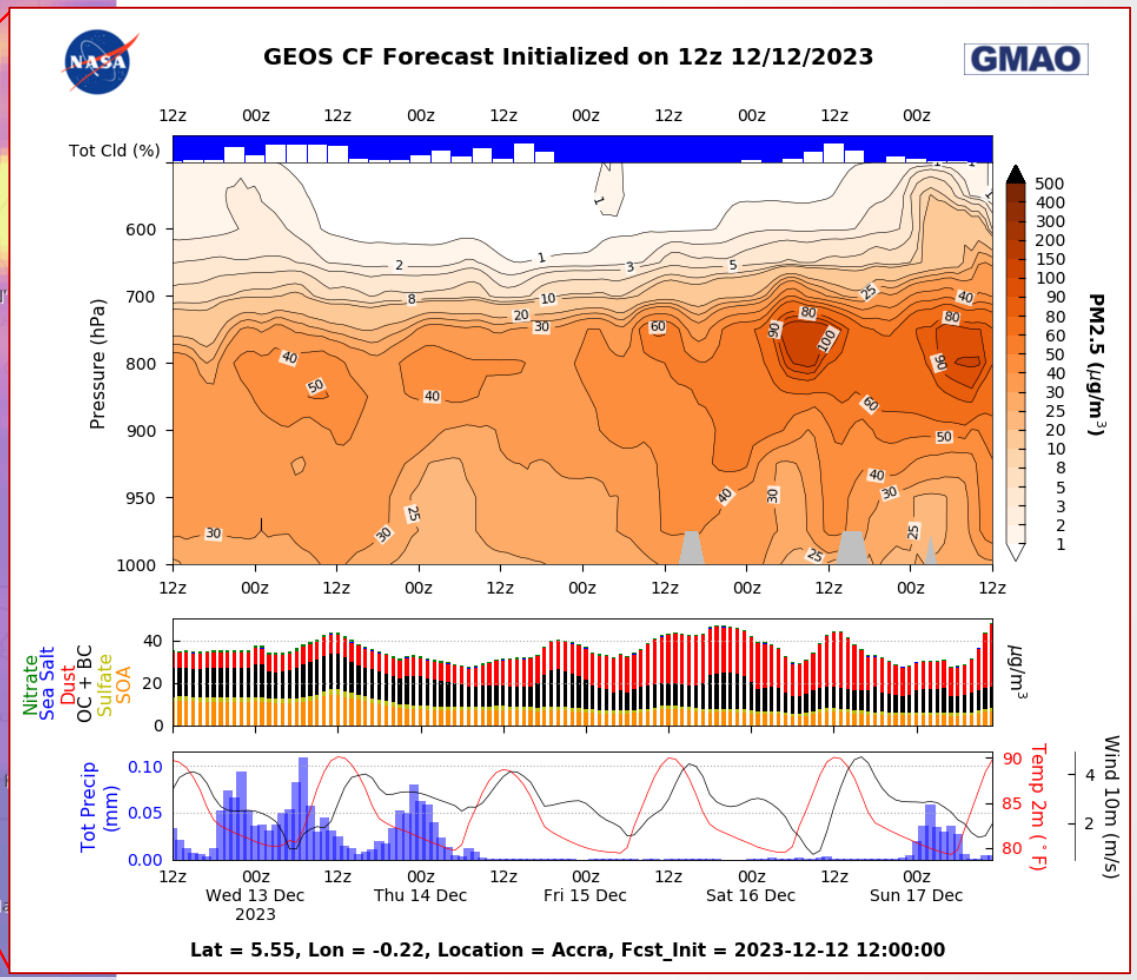
MEGACITIES

Accra

ACTIVE CAMPAIGNS

--Select a Station--

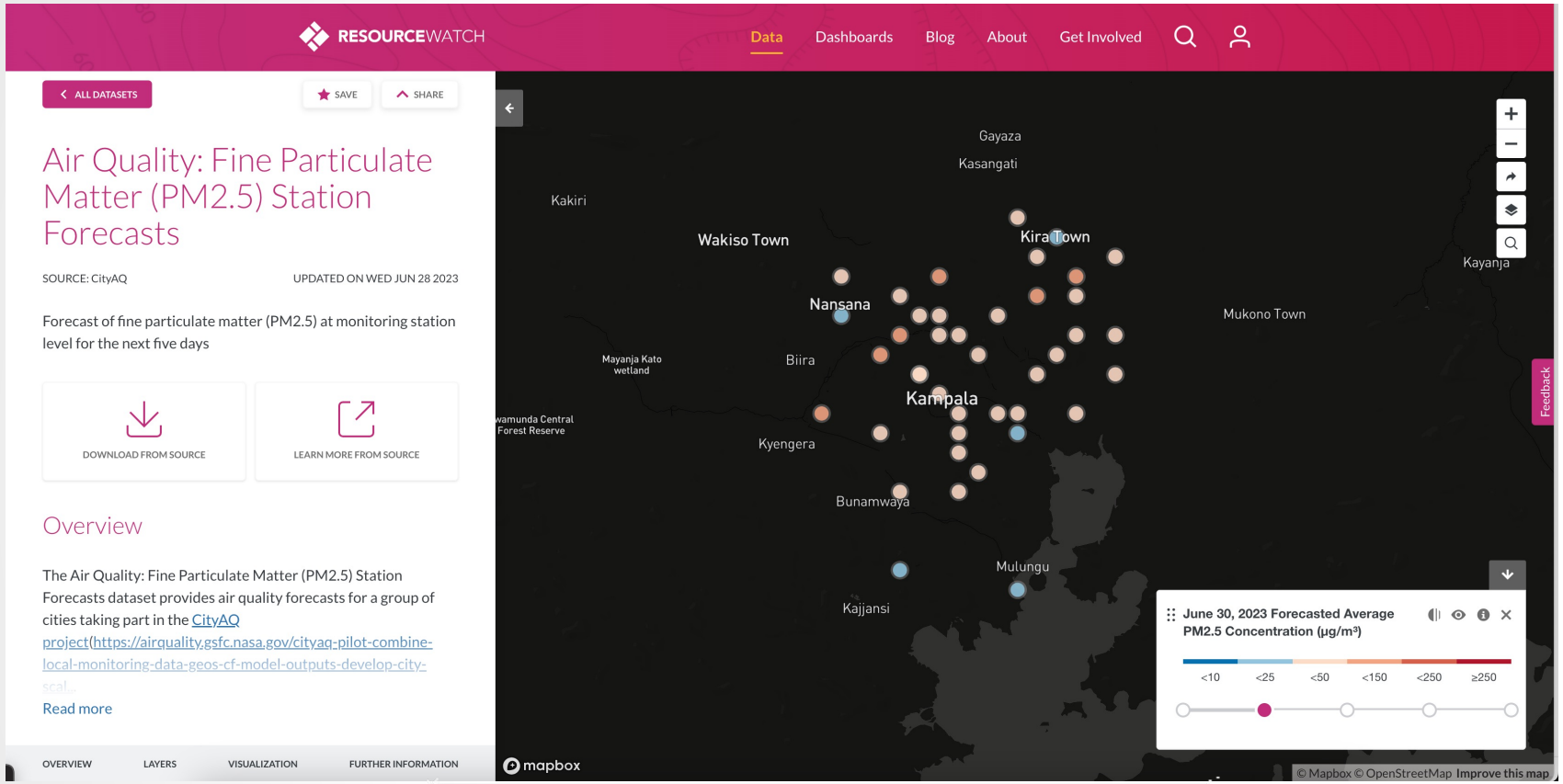


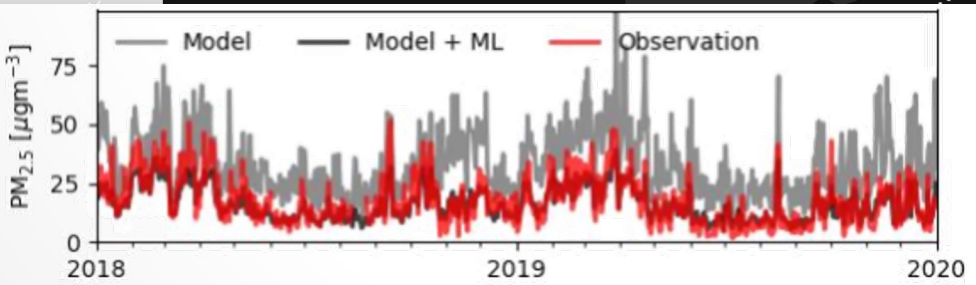


Source: FLUID interactive map https://fluid.nccs.nasa.gov/cf_map/

Data Fusion Approaches

WRI CanAIRy Alert: bias-corrected model forecasts





GEOS-CF global forecast

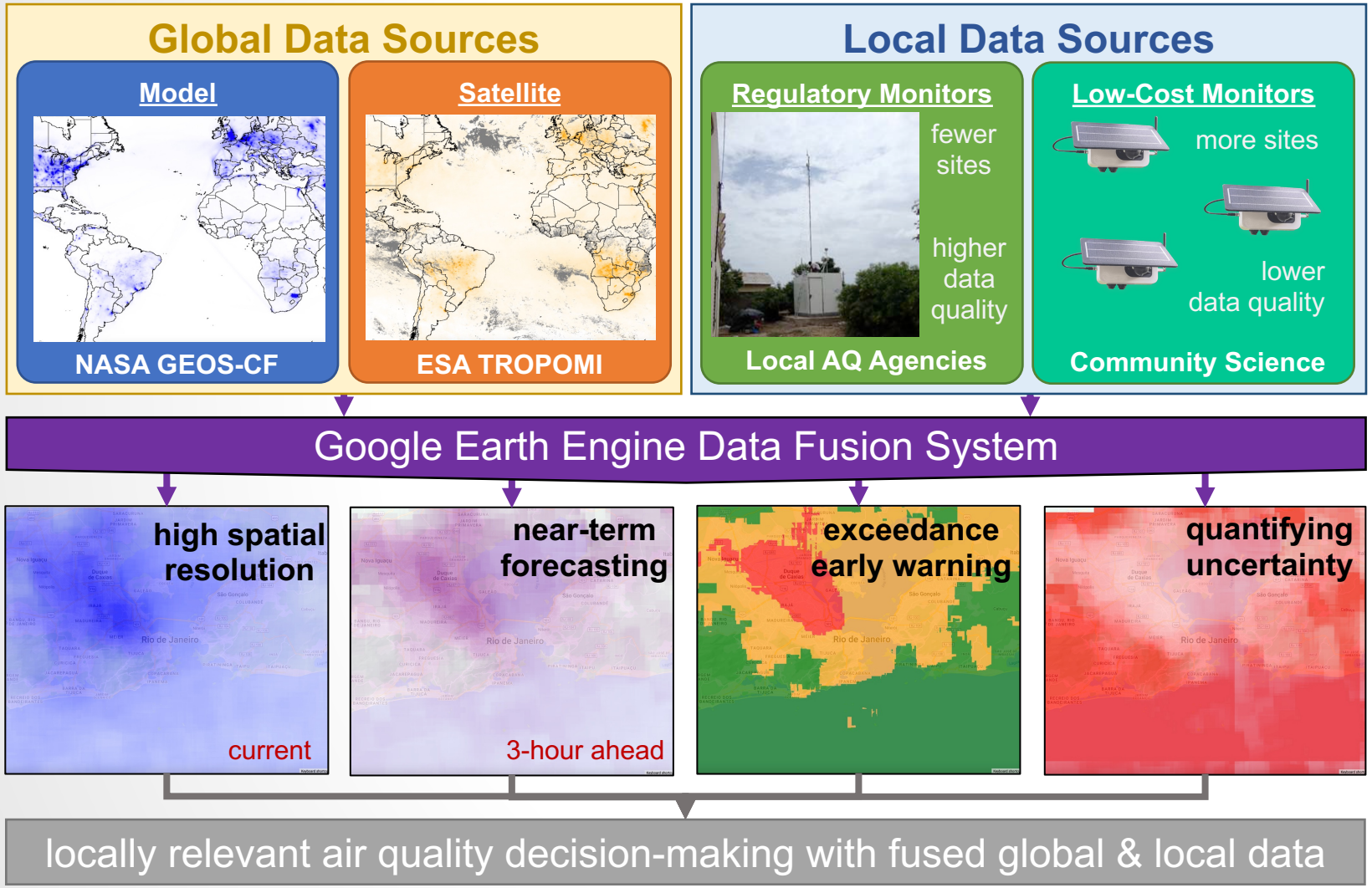
AirQo local measurements

XGBoost Machine Learning Calibration (needs 1+ year of data)

local bias-corrected custom forecast for each monitor site

Source: World Resources Institute CanAIRy Alert
https://www.wri.org/initiatives/canairy-alert

Air Quality data fusion in Google Earth Engine



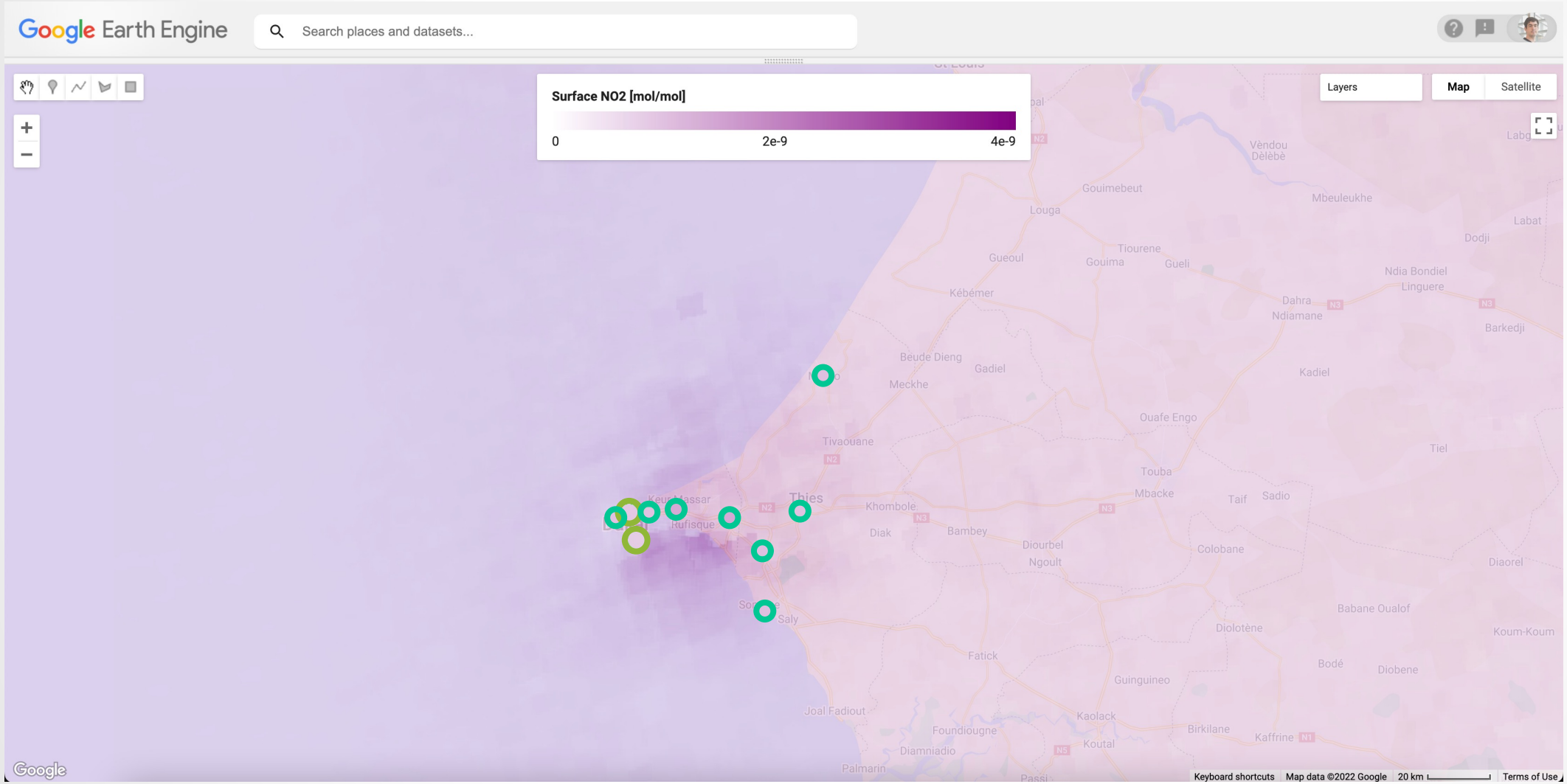
Our project integrates diverse **global** and **local** air quality data sources…

…using the cloud computing platform of **Google Earth Engine**…

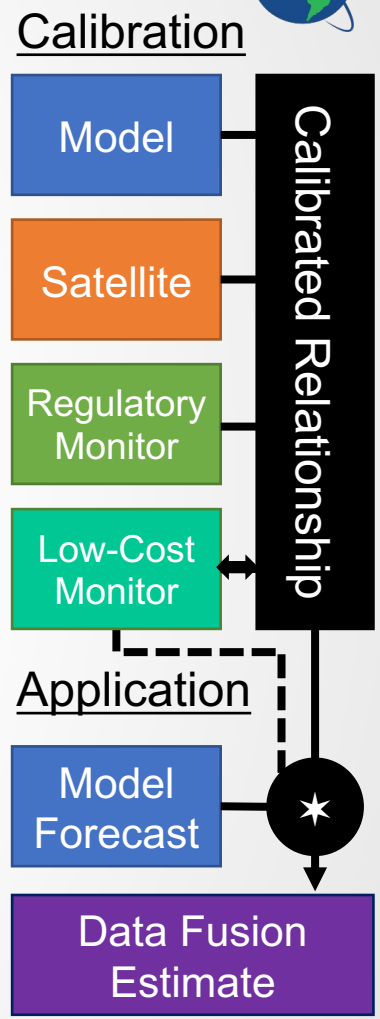
…to provide synthesized **estimates** and **forecasts** of air quality at a **local scale** but with a **global scope**…

…which will be freely accessible by air quality managers worldwide, facilitating their **decision-making**.

Demonstration of Data Fusion in GEE (preliminary)



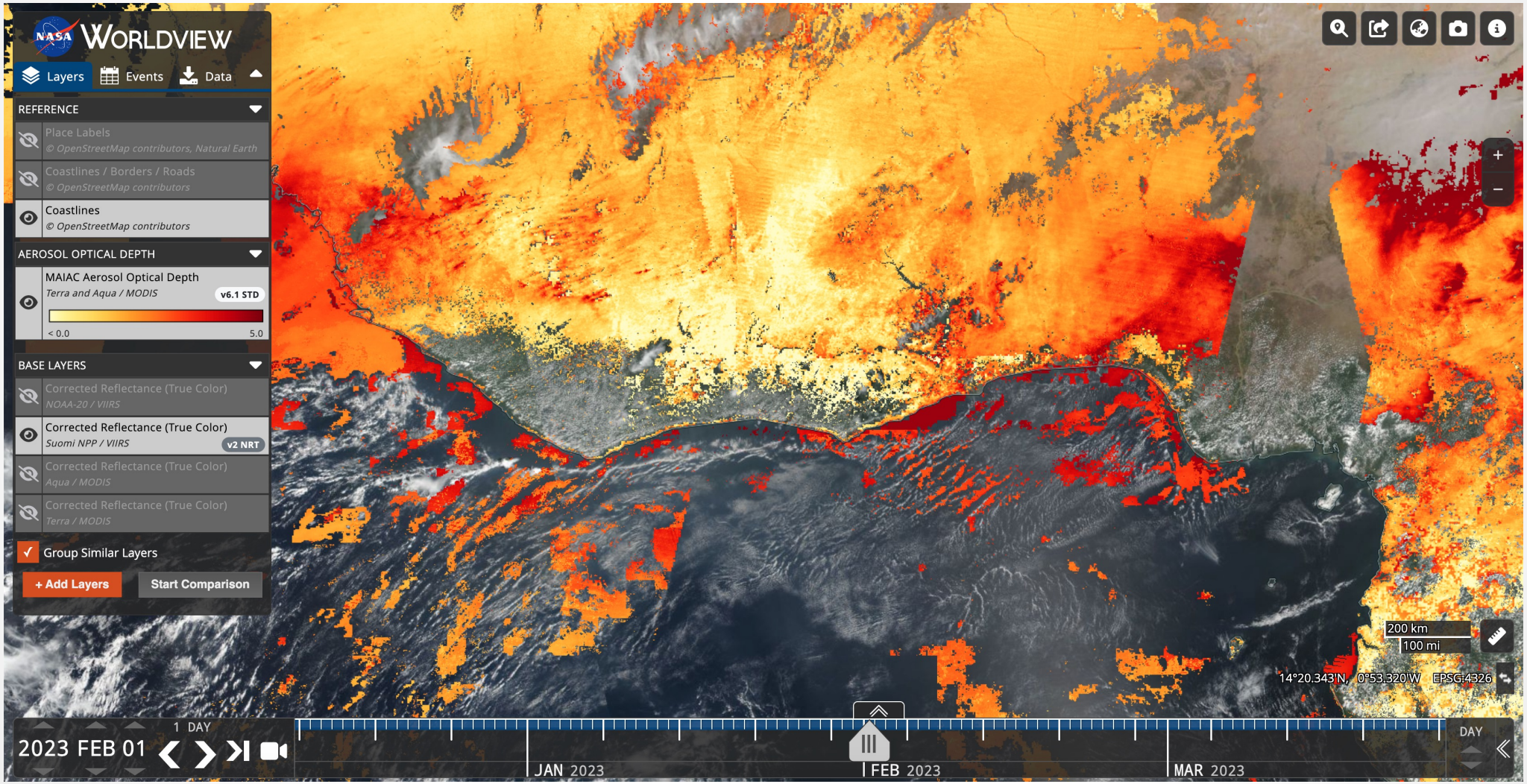
Source: https://code.earthengine.google.com



NASA Data & Training Resources

NASA Worldview

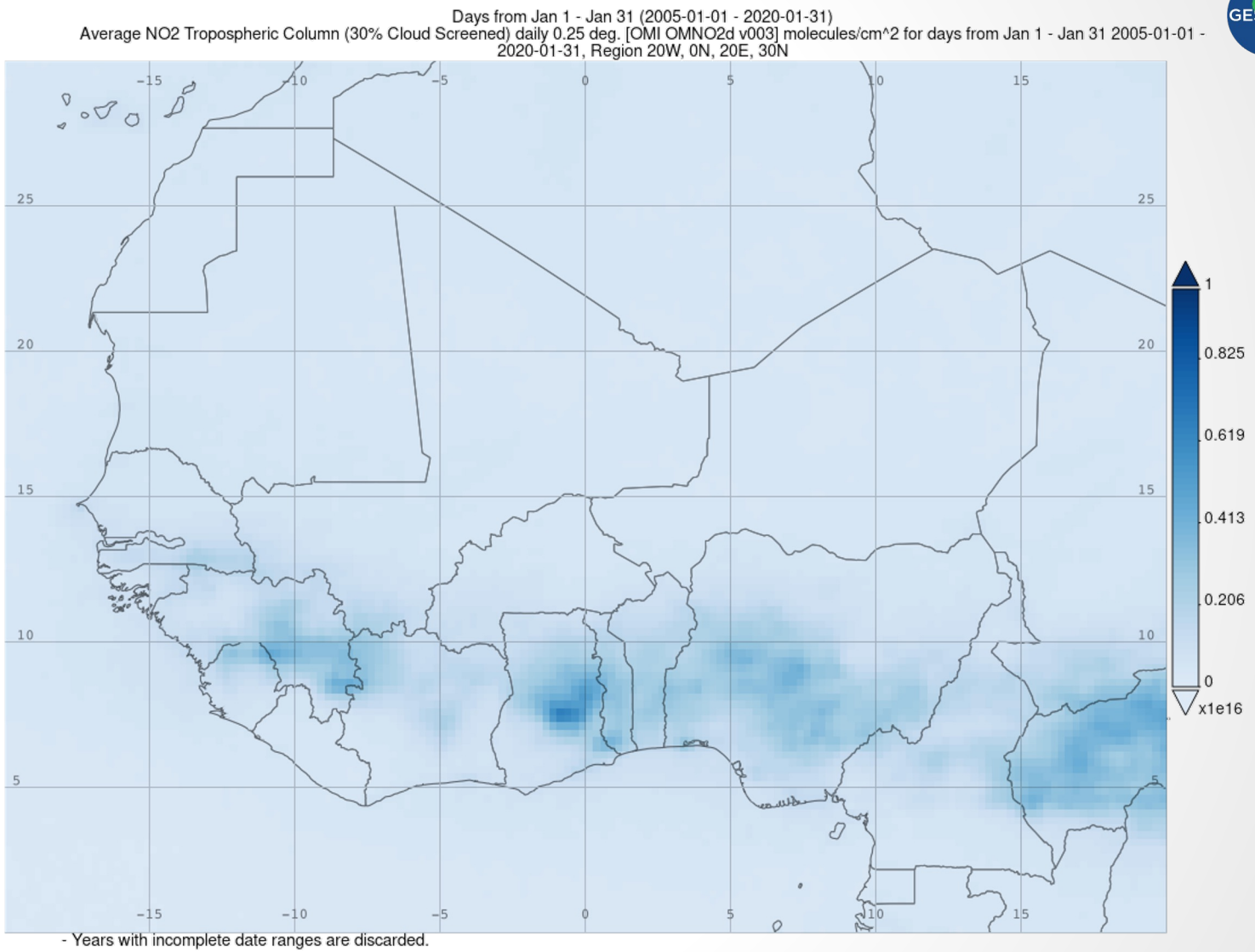
https://worldview.earthdata.nasa.gov



NASA Giovanni

https://giovanni.gsfc.nasa.gov/giovanni

- Work online with many gridded NASA data products (Level 3 & 4)
- Perform simple analysis
  - spatial & temporal averaging
  - recurring/periodic averages
  - differences
- Plot results
  - area colormaps
  - time series
  - scatterplots
  - correlation plots
  - histograms
- Download data subsets
  - NetCDF
  - GeoTIFF
  - KMZ

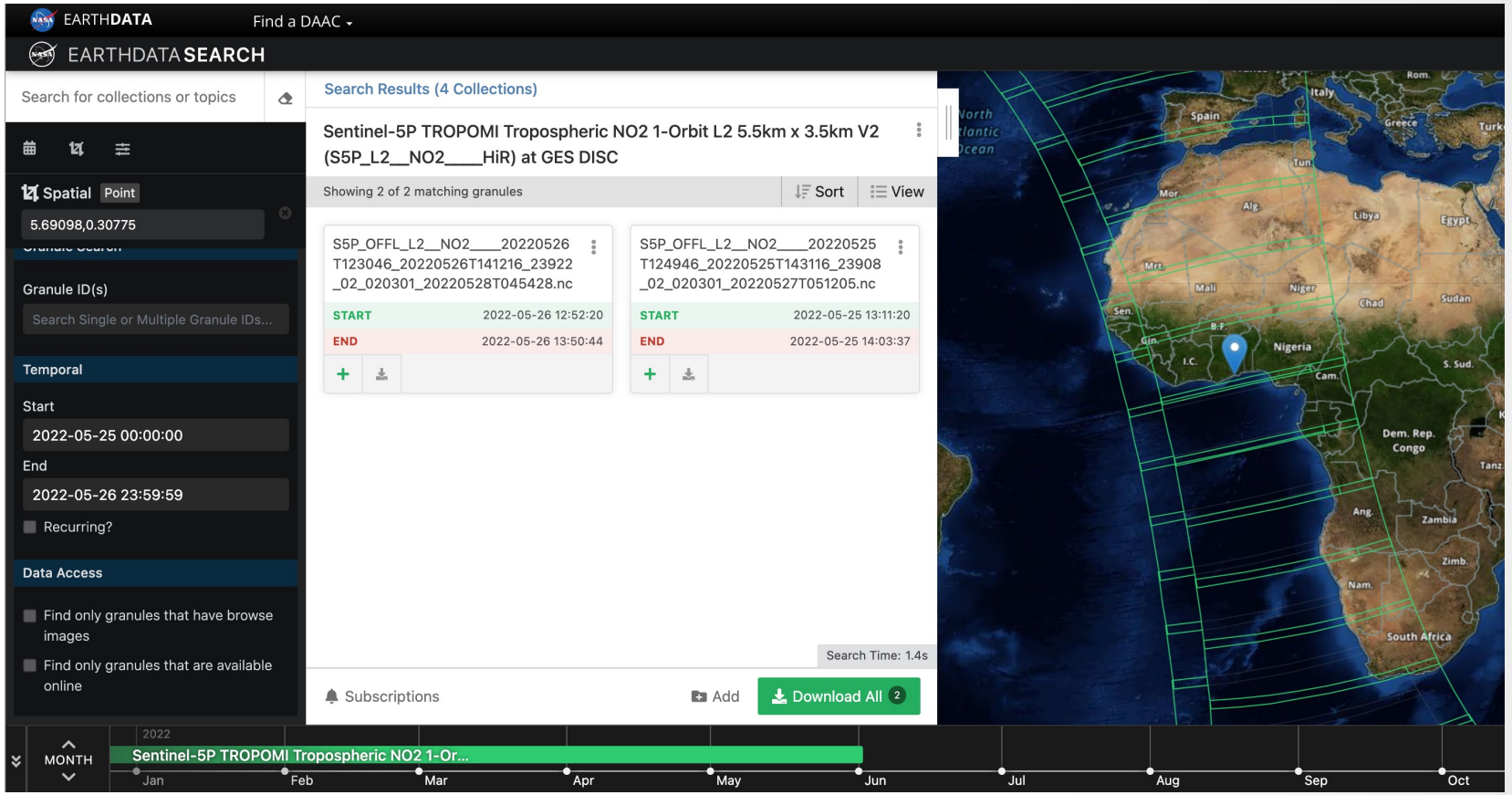


NASA Earthdata search

https://www.earthdata.nasa.gov/

Online tool for sub-setting and downloading NASA (and other) model & satellite datasets for offline analysis

- Search by spatial and temporal bounds
- Select and download relevant datasets
- Filter options for different spatial and temporal resolutions, processing levels, and data access options



Getting Started with the Health and Air Quality Data Pathfinder:
https://www.earthdata.nasa.gov/learn/pathfinders/health-and-air-quality-data-pathfinder

NASA Applied Remote Sensing Training (ARSET)

https://appliedsciences.nasa.gov/arset

ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.

Our trainings are:

- Online and in-person
- Open to everyone
- Live, instructor-led, or self-guided
- Provided at no cost, with materials and recordings available from our website
- Often multi-lingual
- Tailored to those with a range of experience in remote sensing, from **introductory** to **advanced**

ARSET offers trainings for:

- Disasters
- Health & Air Quality
- Land Management
- Water Resources
- Climate

Relevant Past ARSET Trainings

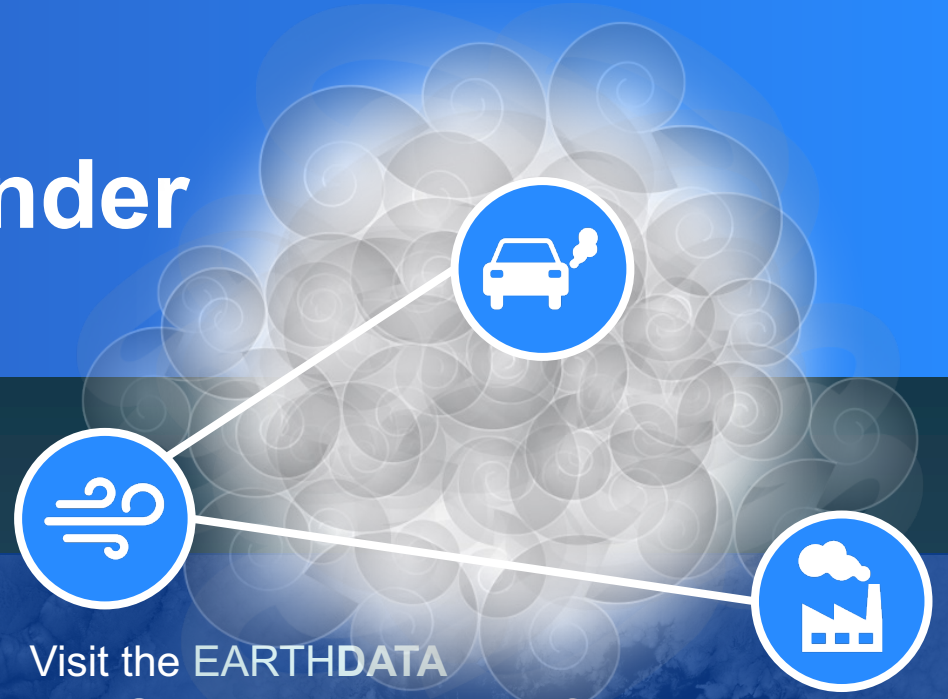
ARSET Health and Air Quality Trainings

- Introductory Level: Fundamentals of Remote Sensing (self-paced interactive online course)
- Introductory Level: High Temporal Resolution Air Quality Observations from Space (2018)
- Introductory Level: An Inside Look at how NASA Measures Air Pollution (2020)
- Introductory Level: Fundamentals of Machine Learning for Earth Science (2023)
- Intermediate Level: Satellite Observations and Tools for Fire Risk, Detection, and Analysis (2021)
- Intermediate Level: Accessing and Analyzing Air Quality Data from Geostationary Satellites (2022)
- Intermediate Level: Satellite Remote Sensing for Equity & Environmental Justice (2023)
- Advanced Level: High Resolution NO_2 Monitoring From Space with TROPOMI (2019)
- Advanced Level: MODIS to VIIRS Transition for Air Quality Applications (2020)
- Advanced Level: Introduction and Access to Global Air Quality Forecasting Data and Tools (2021)
- Advanced Level: Tools for Analyzing NASA Air Quality Model Output (2022)

EARTHDATA Offers

The Air Quality Data Pathfinder

for Your Research & Applications



Air pollution is one of the largest global environmental and health threats. NASA provides data resources to better understand the movement of pollutants and the impact of events leading to poor air quality. This Pathfinder helps you access, and leverage data acquired from NASA's satellite, airborne, and ground-based missions and campaigns.

Available Data Types:

- Aerosols
- Trace Gases (e.g., Nitrogen Dioxide, Sulfur Dioxide, Carbon Monoxide, etc.)
- Weather (e.g., Air Temperature, Clouds, Precipitation, etc.)
- Land Surface (e.g., Soil Moisture, Surface Reflectance, Topography, etc.)
- Human Dimensions

Data are from satellites, airborne and ground-based platforms, and models, including:

- AIRS
- AMSR2
- GPM
- MODIS
- OLI/TIRS
- OMI
- OMPS
- SMAP
- TROPOMI
- VIIRS
- GEOS
- MERRA-2

Visit the EARTHDATA

Air Quality Data Pathfinder

for more information:

- Commonly Used Datasets for Air Quality Research and Applications
- Tools for Using Data
- Resources for Applying and Connecting NASA Data
- GIS Resources
- Tips for Getting Help and Connecting with NASA experts
- Tutorials and more!

Health and Air Quality Applied Science Team (HAQAST)

https://haqast.org/

"Our goal is to use NASA's data and satellites to pursue cutting edge applied research in order to keep you healthy and safe."

- Use NASA satellite & other data to help solve real-world public health and air quality problems.
- Work around the world on diverse issues related to health and air quality.
- Collaborate with public stakeholders to help guide long-term research.
- "Tiger Teams" pursue short-term, high-impact projects in small groups.

Getting started with NASA satellite data for health and air quality:
https://haqast.org/getting-started/

Takeaways

- Satellite data can be useful for filling in gaps in our understanding of surface air quality.
- However, satellites do not directly measure air quality; it might be inferred indirectly using satellite data and other information.
- Many free resources exist to access, visualize, and interpret satellite and satellite-derived data.
- Training and community resources: NASA ARSET, HAQAST.

Thank You!